# ELECTROMECHANICAL components & systems DESIGN 7

JUNE 1958

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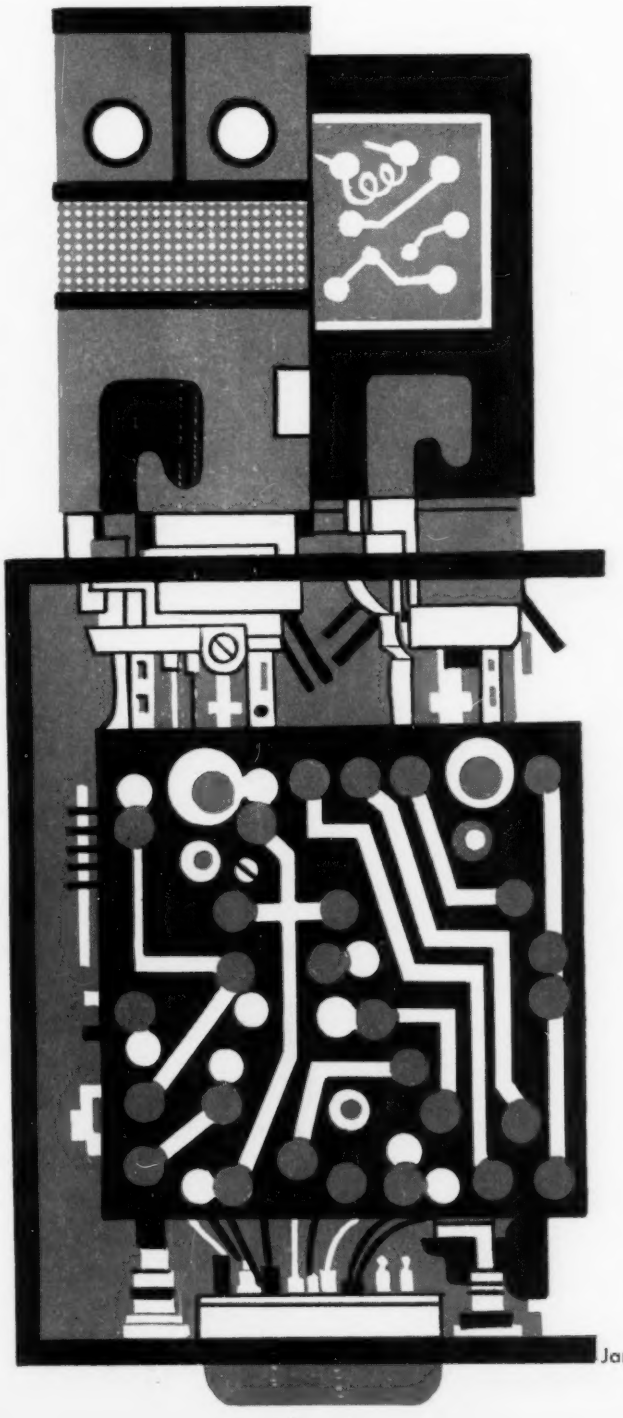
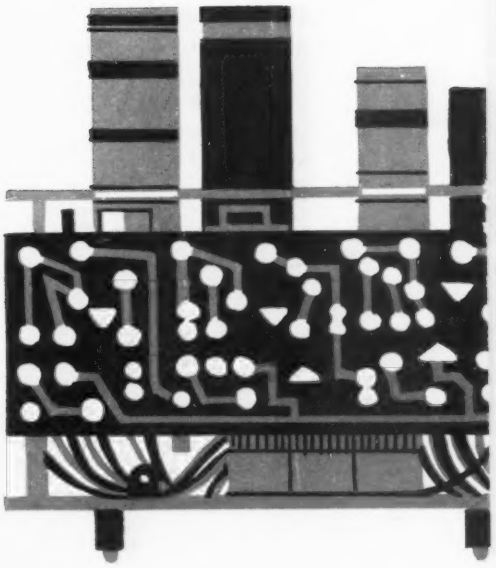
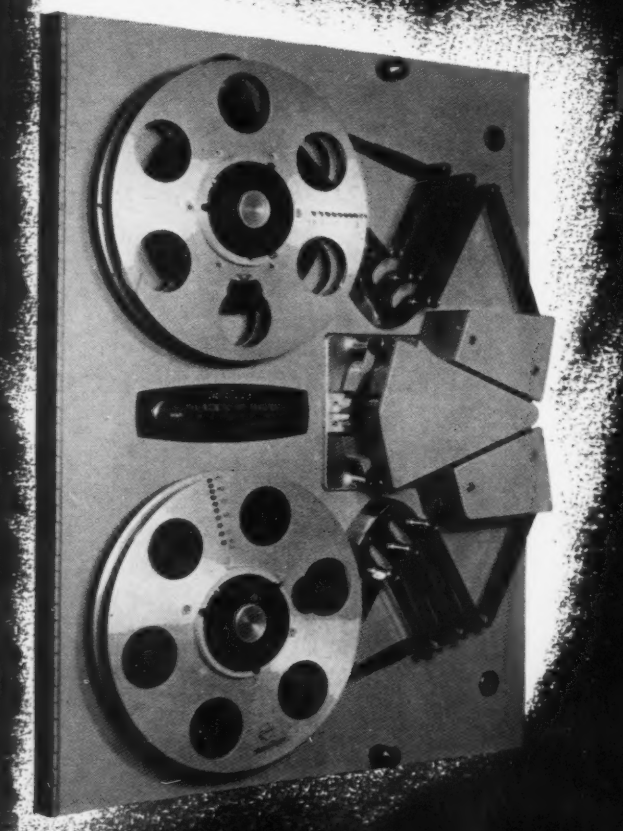


James Flora





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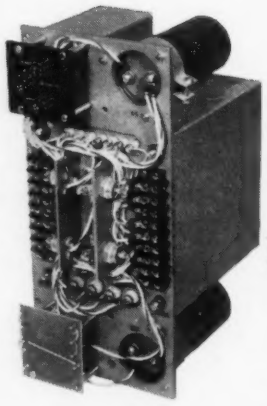

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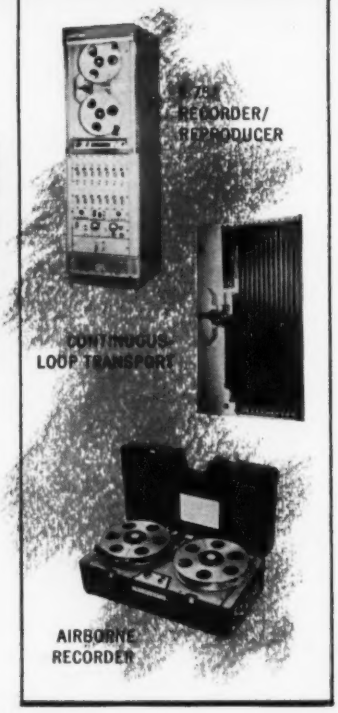


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## CONTENTS


**COMPONENTS DESIGN**

4 DIGITAL VOLTMETER
*Servo positioned potentiometer uses stepping switches in automatic range switching circuit to provide extended range of input values.*

8 SIMPLIFIED DESIGN OF COLOR PICTURE TUBES
*Single-gun construction of color tubes eliminates beam convergence problems Post deflection focusing and phosphor strip positioning further enhance color resolution.*

12 ELECTROMECHANICAL BRAKE
*Redesign gets more brake in less space and requires lower maintenance. New low-loss magnet produces high force at low coil power.*

**SYSTEM DESIGN**

14 THE TRANSISTOR REGULATED POWER SUPPLY AS A FEEDBACK CONTROL SYSTEM
*How to design transistorized power supplies that function accurately under severe ambient conditions.*

20 GYRO PACKAGE SHAKEDOWN
*System and procedure for vibration testing of turn rate transmitter under operating conditions.*

24 A-C ADJUSTABLE SPEED DRIVE
*A-C and d-c motors on single shaft. Shunt field of d-c motor, excited by semiconductor-rectified a-c line voltage, is controlled by rheostat to adjust speed. Rectified slip power of a-c motor converted to output power in d-c motor.*

**MANAGEMENT**

30 VALUE ENGINEERING: Design For Profit
*New technique for measuring the true value of everything that goes into a design before production investment is made.*

36 CASE HISTORIES IN SPRING DESIGN
*Consultation with specialists at spring manufacturers is often an easy way out of spring design problems.*

**DESIGN TIME SAVER**

44 EVALUATING INSULATED SPLICES
*Splice performance is rated quantitatively on how the splice compares dimensionally mechanically and electrically to the length of cable it replaces.*

3 EDITORIAL

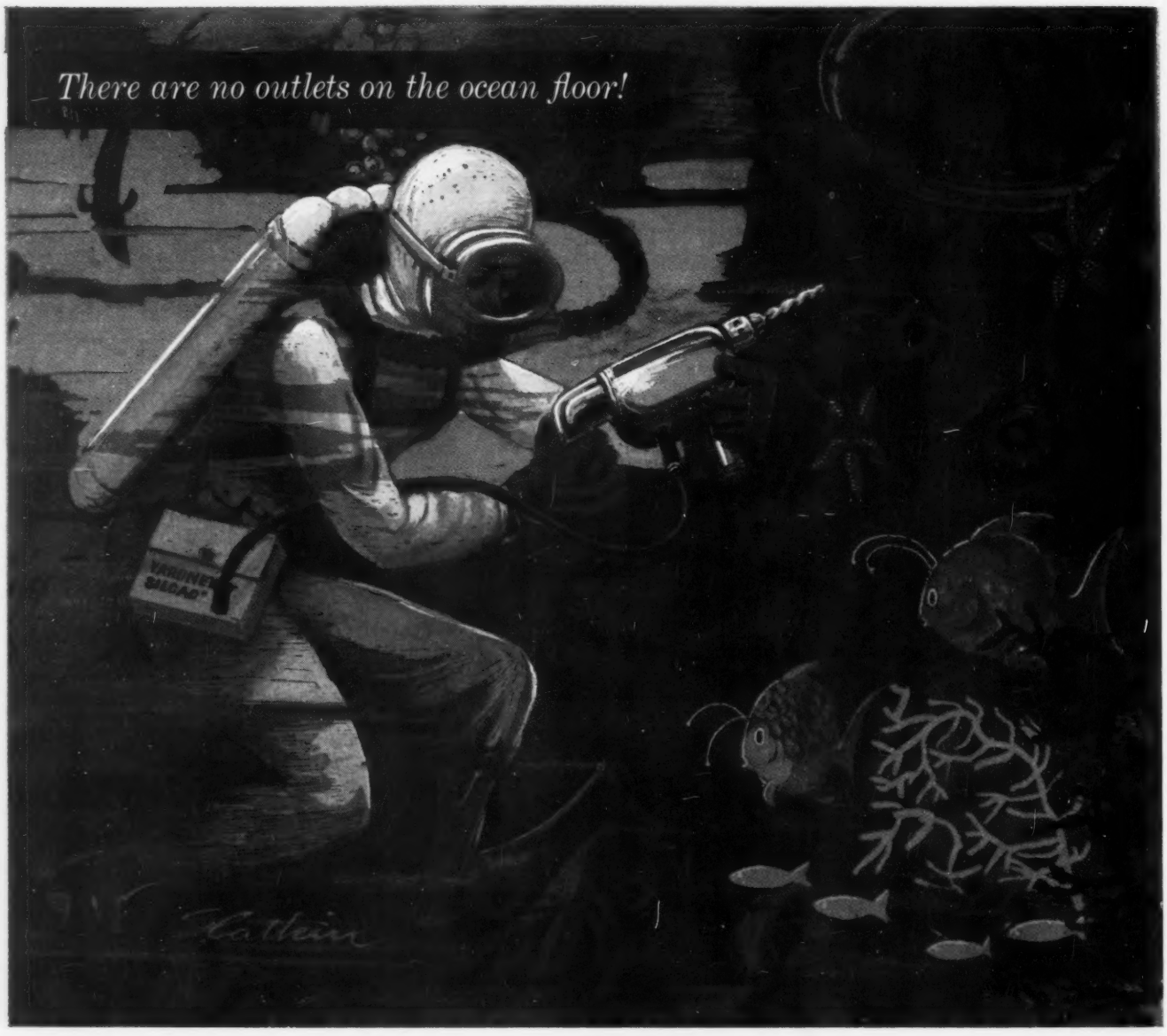
47 ADVERTISERS' INDEX


## STAFF COLUMNISTS


26 Sidney A. Davis • DAMPING FACTORS
*Dangers in single source "special" components*

48 David Bandel • THE ALPHAS AND BETAS OF IONIZATION


James Flora, our Art Director, saw this month's cover design in the configurations of the digital voltmeter illustrated on page 4.

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# Components Digest

Highly developed mathematics of systems and machine computation techniques have made the synthesis of complex systems seem easy, belying the ultimate complexity of final hardware. In our April 1958 issue we pointed out dangers in losing sight of the performance limitations of system components and of their departure from idealized transfer function representation.

But awareness of these dangers does not dispose of them. Information as to available components is never complete, and worse still, necessary data on performance limitations of known components is often unavailable.

Searching for the right component for a job can take a lot of valuable engineering time—looking through indices of manufacturers, sending for catalogues and data sheets, and subsequent further queries for details. And throughout the search there is always the possibility the best choice will be overlooked.

A first-class central file of manufacturers' catalogues contributes immeasurably to overcoming these delays and uncertainties, but it still leaves much to be desired. Nomenclature and manner of presentation are non-uniform; specifications are frequently vague, particularly for those borderline characteristics the engineer must pin down; a lot of significant data is not presented—the manufacturer tends to omit those characteristics that reflect unfavorably on his product. The project engineer who makes assumptions where data is incomplete takes a calculated risk.

The editors of ELECTROMECHANICAL DESIGN have been surveying the problem of gathering and summarizing data on electromechanical components for our readers. It can't be done overnight, but we believe we can cover available data on one class of components, such as gyros, synchros, servomotors, etc., each month so that in time a fairly complete set of reference charts will be achieved, replacing vast quantities of manufacturers' catalogues. If a class of components is too large to be summarized in seven or eight pages of charts, we will divide it into appropriate sub classes. This department, to be called Components Digest, will be crowded with facts obtained directly from the manufacturers in answer to very specific questions designed to point up limitations as well as special features.

The first section of Components Digest will be in an early issue. We are reporting it now in the hope that some of you will contribute your thinking to our plans.

Robert B. Brotherston
EDITOR


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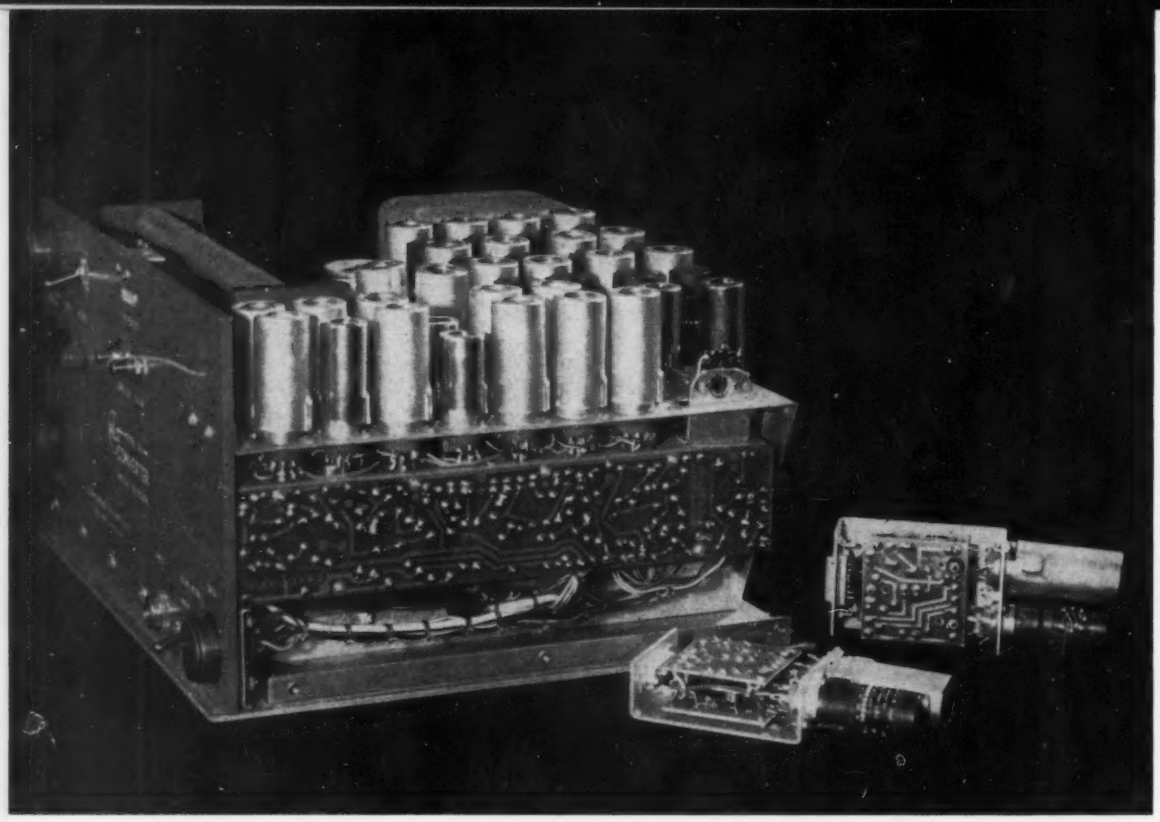

**Digital Voltmeter instruments are often encased in standard rack-mounting cabinets for inclusion in laboratory instrumentation systems. Printed circuits and modular plug-in subassemblies make the modern digital voltmeter easy to maintain at rated calibration.**

## DIGITAL VOLTMETERS

### Design Aspects

Exemplifying the degree of accuracy and reliability towards which electromechanical measuring instrument manufacturers are striving is the digital voltmeter produced by Non-Linear Systems, Inc., of Del Mar, California. Operating as a digital self-balancing potentiometer, the digital voltmeter automatically compares an unknown input voltage with a variable feedback voltage originating in the voltmeter itself; and when a balance is obtained between the two voltages, provides the value of the input voltage as an edge lighted display of digits, complete with decimal point and polarity.

Complete familiarity with the operation of the digital voltmeter is best obtained by first understanding the principles involved in the operation of a basic potentiometer circuit shown in Fig 1. The potentiometer is balanced when the tap of the variable-voltage divider has been adjusted such that the voltage, $E_0$, exactly equals the unknown input voltage.

This conditions of balance is ideal in voltage measurement in that with no input current flow the circuit being tested is in the unloaded condition assuring maximum accuracy of the reading. Determining the value of the voltage, $E_0$, needed to balance the input voltage provides the value of the input voltage. The value of the voltage, $E_0$, bears the same ratio to a known reference voltage as that portion of the

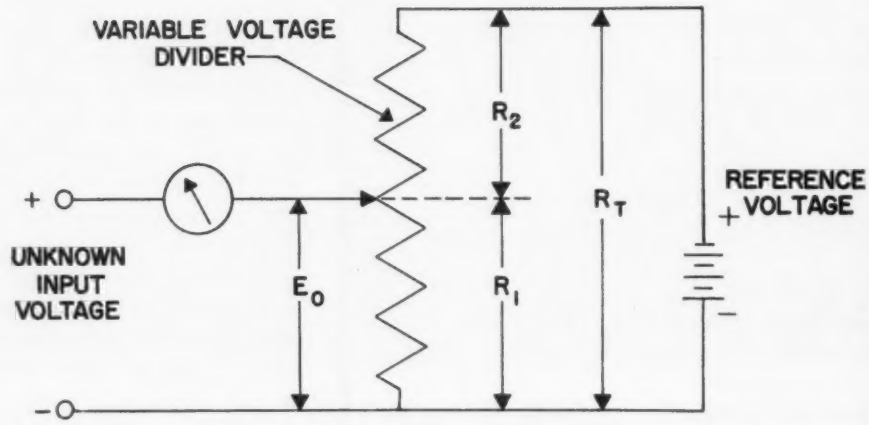


**Fig 1—Basic Potentiometer Circuit. Digital voltmeter is actually a variable voltage divider that operates in finite, digital steps. The output reading is the result of comparing an unknown input voltage to a portion of a self-contained reference voltage. The output reading, $E_0$, is always $R_1/R_T$ (Reference Voltage). The ratio of $R_1$ to $R_2$ changes in precise steps.**

variable resistor between the potentiometer arm and the ground point bears to the total resistance of the voltage divider. That is:

$$E_0/\text{Reference Voltage} = R_1/(R_1+R_2) = R_1/R_T$$

The value of $E_0$ is found by multiplying this ratio by the value of the reference voltage.

$$E_0 = R_1/(R_1+R_2)\ (\text{Ref. Voltage})$$

If the reference voltage comes from an accurate and stable source and the variable voltage divider resistor is carefully calibrated, the value of $E_0$ can be read directly from the calibration.

In this basic form, potentiometers suffer from several disadvantages. The most annoying disadvantage is that in measuring an unknown voltage, the potentiometer must be manually adjusted to bring about a balance. This requires not only matching polarities of input and reference voltages, but carefully moving the tap of the voltage divider until a null is observed on the galvanometer. Another distinct disadvantage is that in this basic form the potentiometer is limited to measuring voltages of amplitudes which do not exceed the reference voltage values.

Still utilizing the basic principle of the potentiometer, the NLS digital voltmeter eliminates these disadvantages by automatically accomplishing the balancing operation including the polarity matching, and providing for an extended range of input voltage values through the use of an automatic

range switching circuit.

Fig. 2 shows a simplified functional schematic of the digital voltmeter. The unknown input voltage is fed through a range circuit into one side of a chopper. A feedback voltage obtained from an incremental voltage divider is fed into the other side of the chopper. Alternately sampling the input and feedback voltage, the chopper feeds an error amplifier. When an inequality exists between the amplitudes of the input and feedback voltages, the output of the chopper appears as a square wave with amplitude proportional to the difference in amplitude between the two voltages.

Action of the voltmeter circuitry is to automatically alter the value of the feedback voltage until balance is obtained. A phase sensitive amplifier monitoring the chopper output produces a pulsed output whenever the amplitude of the chopper output exceeds a certain threshold value. These pulses are boosted through thyraton power amplifier and the amplified pulses fed to the polarity, decade and range switches.

Combined with a network of precision resistors which form an incremental voltage divider of the Thompson-Varley type, the switching circuits function to change the magnitude of the feedback voltage to a value that will balance the unknown input voltage as it appears in the output of the range circuit. The switching actions are required to agree with the voltage value of the balancing voltage. These operations include positioning of the decimal point and providing polarity information.

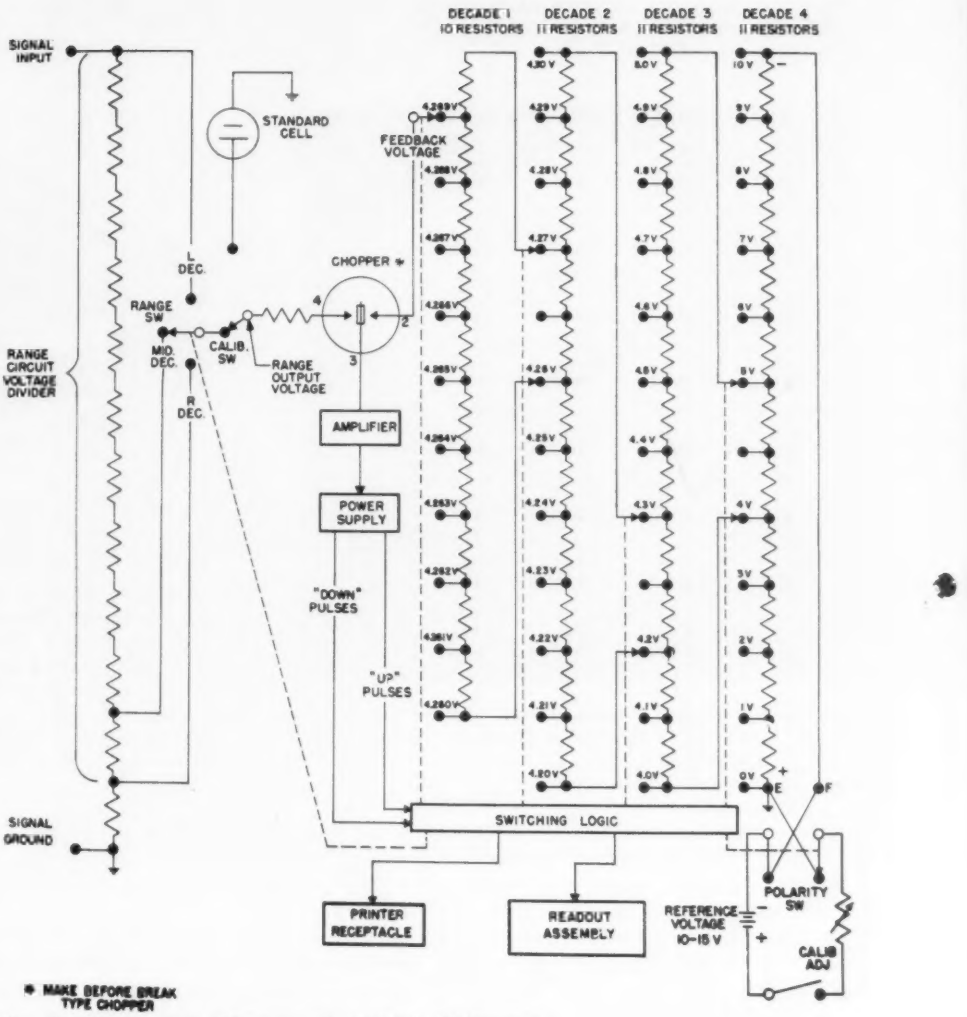


**Fig 2—Functional Digram of Digital Voltmeter.**

## STEPPING SWITCHES PERFORM POTENTIOMETER FUNCTION

Constituting the heart of the digital voltmeter, the switching circuits may be considered as forming a servo positioned potentiometer. Error signals in the form of pulses from the power amplifier cause the stepping switches to "step" from contact to contact until the feedback voltage obtained from the incremental voltage divider balances the input voltage. At balance the error signals are reduced to zero and the stepping switches hold their immediate positions unless a change in input voltage initiates another error signal.

The incremental voltage divider is formed by connecting a network of precision resistors to the stationary contacts of the rotary stepping switches. Each contact of the stepping switches represents a finite position on the voltage divider. As the switches are stepped from contact to contact, the voltage existing at those points on the voltage divider are made available for comparison with the unknown input voltage. The voltage divider employs a stepping switch and a resistor string for each significant figure making up the readout. Since the feedback voltage must change in finite steps corresponding to fixed points on the voltage divider, the readout is always within plus or minus one digit of the feedback voltage. In a four digit readout voltmeter this would correspond to an accuracy of one part in 10,000 or 0.01 percent.

Polarity matching of the unknown input voltage with the reference voltage is managed by the switching circuits. Error pulses from the power amplifier are first fed to a polarity switch which automatically adjusts the polarity of the reference voltage by actuating a double-pole double throw switch.

Excitation voltage for the potentiometer is referred to as the reference voltage and is provided by an electronic power supply regulated by temperature compensated zener diodes. Calibration of the potentiometer is accomplished by employing a standard cell as the input voltage and adjusting the voltage across the voltage divider until the digital readout indicates the value of the cell potential. A variable resistor placed in series with the ref-

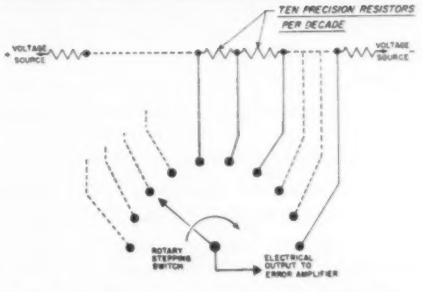


**Fig 3—Heart of the digital voltmeter is a rotary stepping switch. As the switch is rotated by a servo motor, a resistance voltage divider is varied in finite, digital steps. Electrical output of the arm of the stepping switch-generated feedback voltage is equal to the input voltage, stepping switch rotation ceases and a stable readout occurs.**

**Fig 4—Mechanical design of the digital voltmeter hinges upon basic repetitive modules such as the unit shown here.**

**Fig 5—Basic chassis construction of rack-mounted unit shows modular concept. These same modules can be assembled as an upright bench test instrument. Digital voltmeters automatically indicate polarity and decimal point. Switching circuits within the instrument cause four digits to appear for each voltage reading from 0.0001 to 9999 volts. A situation of 0092 volts, for example, cannot occur; the meter would read instead 92.00, taking full advantage of all four digits.**

erence voltage supply is adjusted manually until the correct readout is obtained. In this manner, calibration of the instrument is possible while the instrument is being used. Some digital voltmeters automatically perform this calibration.

Making it possible for the digital voltmeter to handle input voltages with magnitudes greater than that of the reference voltage, the range circuit automatically reduces input voltages to a level within the range of the reference voltage. This reduction is accomplished by applying the input voltage across a tapped voltage divider network composed of the range switch and twelve precision resistors. The values of the resistors are established to provide voltage dividing factors of, for example, ten and one hundred in four-digit models. As the range circuit functions to reduce the input voltage to the proper level, it provides indication of its action by dictating the position of the decimal point in the readout.

### DIGITAL LOGIC

Cleverly combining the balancing action of the stepping switches with a pulse routing action makes it possible to employ unidirectional rotation switches in the voltmeter. Rather than command forward and backward rotations to permit balancing of the potentiometer circuit under conditions of increasing and decreasing magnitudes of input voltages, the switches are always stepped in a forward direction, but the actuating pulses are routed to the switches in such a manner that a logical sequence towards balance is obtained.

Basic in the employment of this switching logic is the generation of pulses in two pulse channels. Whenever the absolute magnitude of the input voltage exceeds the absolute magnitude of the feedback voltage, the error amplifier generates "up" pulses in the "up" pulse channels. "Down" pulses are generated whenever the absolute magnitude of the input voltage is less than the absolute magnitude of the feedback voltage.

Both the "up" and "down" pulses cause the stepping switches to proceed in a forward direction. However, the digital logic employed causes the "up" pulses to drive each switch (starting with the right most digit) towards 9 and "down" pulses to drive each switch (starting with the right most digit) through the nine position towards 0. This procedure results in a logical balancing sequence calling for both "up" and "down" pulses as the feedback voltage becomes alternately greater or less than the input voltage.

### NEED FOR PRECISION DICTATES DESIGN CRITERIA

While the potentiometer principle employed in the digital voltmeter affords a theoretical accuracy directly proportional to the number of decade switches, the actual working accuracy of the instrument is subject to the effects of a number of other circuit elements.

Most influential in the determination of system accuracy is the accuracy of the voltage divider network. The precision with which each switch position indicates the voltage existing at the switch contact is a function of the precision with which the resistors making up the divider actually divide the reference voltage. This does not demand resistors with individual accuracy equal to the accuracy of the instrument, but it does require a careful matching of those resistors making up the network in order that a precise division be obtained.

Resistance effects other than those directly attributable to the network resistors must also be considered in the design of the voltmeter. Contact resistance of the stepping switches can materially alter the characteristics of the voltage divider networks. Repeated making and breaking of the contacts results in contact resistance changes due to wear.

Thomas E. Nawalinski, Non-Linear Systems' Chief Application Engineer, who supplied us with the material for this article, tells us that a splash lubrication technique incorporated in the NLS voltmeter has not only eliminated errors due to variations in contact resistance, but has also extended the life of the stepping switches tenfold. The technique involves suspending the switches over a reservoir of oil so that the driving mechanism is immersed in oil and as the switch arm rotates, it

passes through the oil. Carrying a portion of the oil with it as it leaves the bath, the switch arm lubricates the contacts as it wipes over them.

Closely allied with the problem of contact resistance is that of leakage. Finite resistances existing between circuit points supposedly isolated from each other can considerably alter circuit characteristics. Extensive research into the means of eliminating these sources has led to the incorporation of extremely high dielectric materials as insulators in the voltmeter circuits. Even the possibility of leakage due to residual soldering flux has been countered by means of a solvent cleaning process applied to the entire assembly once the soldering operations are completed. Net result of this careful attention to means of eliminating sources of error is an overall unit accuracy of 0.03 percent in the case of the four-digit models. Higher digit capabilities result in greater accuracies through the use of more decade switches.

Digital voltmeters are being built today using relays (mercury-wetted contact relays for extremely high reliability) to accomplish the searching action. However, as a general rule, relays are not as dependable as stepping switches for two very good reasons. One reason is that a series of relays must be used to accomplish the task; and any time several components are used to perform one job, failure of any one of the components (any one relay) will cause the entire circuit operation to fail. The other reason is that, in general, a stepping switch can be built to operate under more severe environmental conditions than a series of relays, unless an exorbitant amount of money is spent for the relays as compared to the stepping switch.

However, extremely reliable higher priced digital voltmeters can be built using mercury-wetted relays if the digital logic and electronic circuit design circumvent certain shortcomings. Such devices will soon be announced by Non-Linear Systems, Inc. For more information on this device

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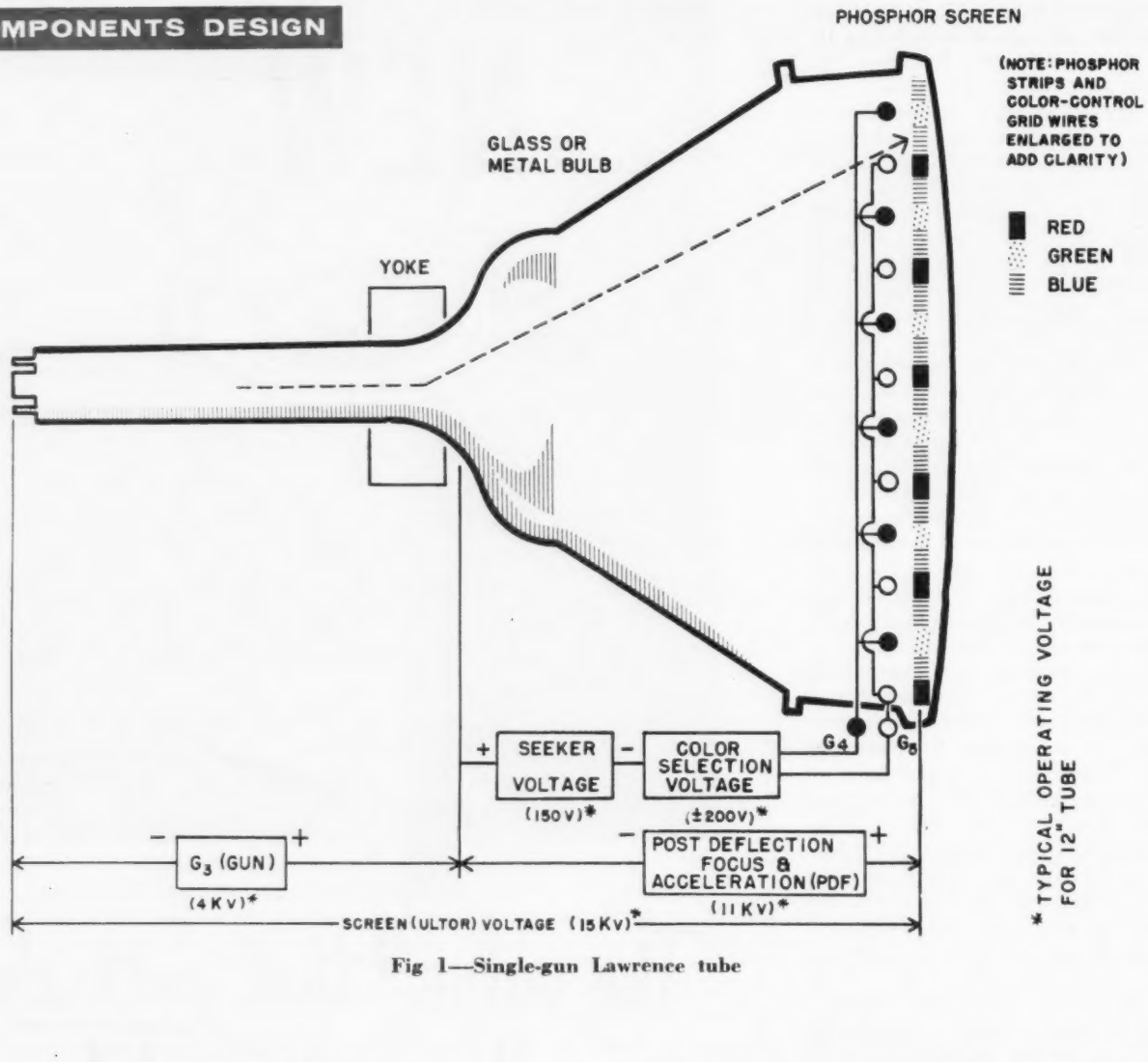



Fig 1—Single-gun Lawrence tube

# Simplified Design of Color Picture Tubes

*Single-gun construction of color tubes, together with positive control of electron beam by a color selector grid eliminates beam convergence problems and gives a bright color display. Post deflection focusing and phosphor strip positioning further enhance color resolution. Manufacturing tolerances of the tube permit its mass production at slightly higher cost than that of black and white tubes.*

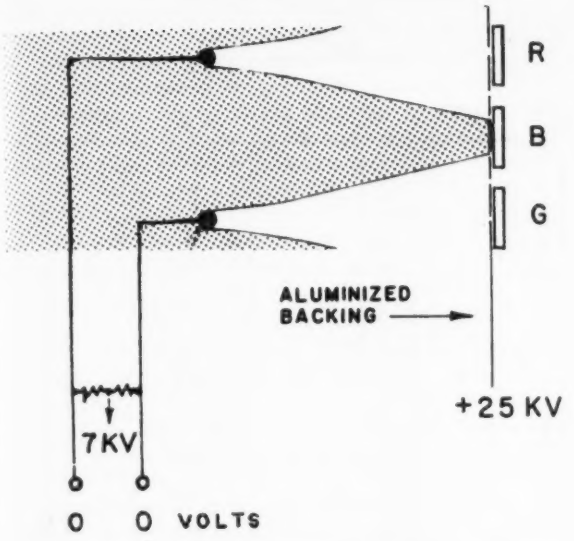
Until the advent of color television, cathode ray tubes were relatively simple devices. Black and white television, like the familiar oscilloscope, required only a uniform, luminous phosphor screen, plus an electron beam that enjoyed considerable latitude as to what part of the screen it was hitting at any moment.

Color television brought the need for profound changes in basic tube design. The simple one gun, one set of grids, and single phosphor tube no longer filled the requirements. Multi-gun, multi-grid, and multi-phosphor tubes were developed to fill the void. Rotating color wheels were also tried. According to Donald R. Cone and Robert H. Rector of Litton Industries' Electronic Display Laboratory, Emeryville, California, none of these, or the numerous other methods employed to produce color pictures, were completely satisfactory until the development of the Lawrence single-gun color tube registered under Litton Industries' trademark, Chromatron.

## ADVANTAGES OF SINGLE—GUN COLOR TUBES

Describing the advantages of the single-gun color tube, Mr. Rector said it has inherent stability necessitating fewer adjustments and simpler circuitry.

"The secret of its simplicity," he said, "lies in the physical construction of the tube itself. Single electron gun construction, together with positive control of the electron beam by a color selector grid, give high resolution color display presentation. Post deflection focusing (PDF) and



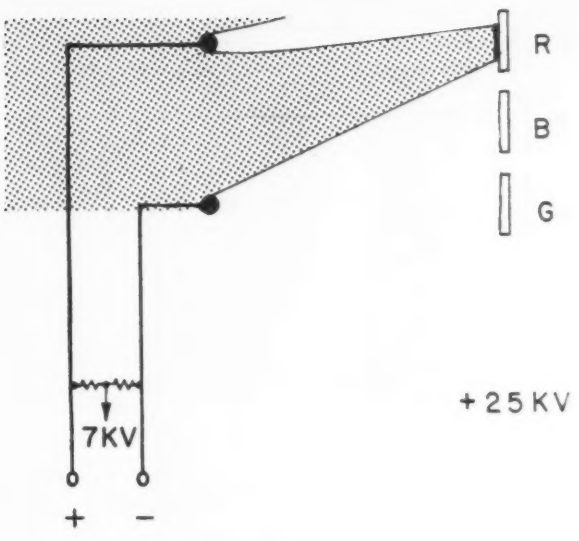




**Fig 3—Color selection in the one-gun color tube. Fig 3a shows the focusing action. A series of cylindrical lenses is formed that has the same focusing action regardless of whether the electron beam scans parallel or perpendicular to the grid wires, or at varying angles as in a rotating PPI scan. A spot size smaller in diameter than the width of the phosphor strip impinges at the electron optical center of the strip. This feature ensures good color resolution characteristics. Color selection is provided by a relatively low switching voltage applied to adjacent grid wires (Fig 3b). Applying the proper polarity and magnitude of switching voltage to the grid wires causes the beam to strike one of the other of the adjacent phosphor strips. Two color presentations would be obtained if both switched fields were of the same color.**

phosphor strip positioning further enhance color resolution."

In a tri-color Chromatron alternate strips of aluminum backed phosphors are placed in a horizontal pattern. Figure 2 shows a typical arrangement for a tube designed for red and green display.

"Single gun construction of color tubes", Rector said, "completely eliminates beam convergence problems associated with other types of multi-gun or spun beam tubes. Color rendition and purity are thus faithfully reproduced, permitting wide application in fields where color indications are so important, as in color temperature measurements."

## TUBE DESIGN CHARACTERISTICS

Post deflection focusing, PDF, is accomplished by mechanical design of the grid with respect to the screen and application of appropriate accelerating voltages to grid and screen. Four kilovolts of acceleration from cathode to color selector grid and eleven kilovolts from grid to screen or phosphor plate provide proper ratio for optimum post deflection focus as well as accelerations requisite for high brightness.

Usually, the electron source is provided by a single electron g un with magnetic focus and deflection applied in a manner similar to that of a 12SP7 tube; however, electrostatic focus or deflection, or both, may be preferred. Most tubes incorporate magnetic deflection with either fixed or rotating deflection yokes.

A slightly positive voltage, relative to color grid potential, is applied to the tube shell. This potential, called the seeker voltage, serves to collect secondary, or stray, electrons and ions from the shell, thus preventing their penetration of the color grid and thereby spurious excitation of the phosphors.

Phosphor strips are generally applied directly to the face of the display tube with the grid mounted the correct distance behind the screen. Another method sometimes employed is to apply the phosphors on a flat plate to which the grid is mounted by insulators. This sandwich is then installed inside the bulb. The first method is usually used with glass tubes and the second with metals; however, either method is applicable to both types of tubes.

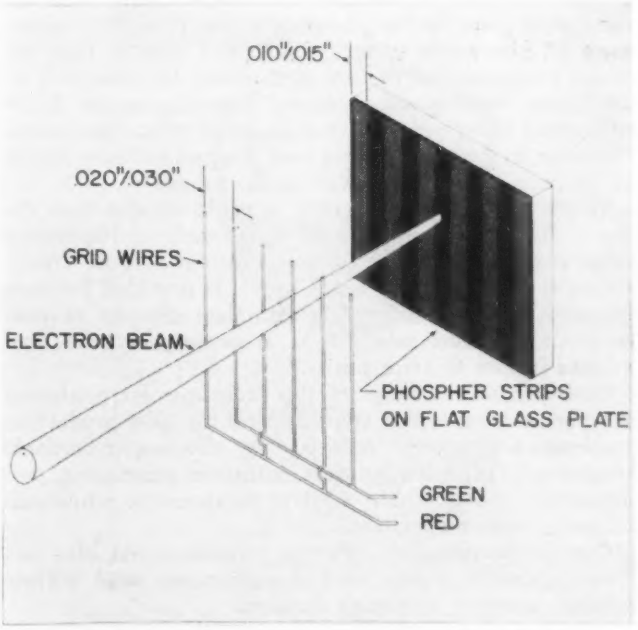



**Fig 2—Typical arrangement for a Lawrence tube designed for red, blue and green display. Alternate strips of aluminum backed phosphors are placed in a horizontal pattern. Between the gun and the screen is the color selector grid. The grid wire spacing provides between 75 and 90 percent electron transparency.**

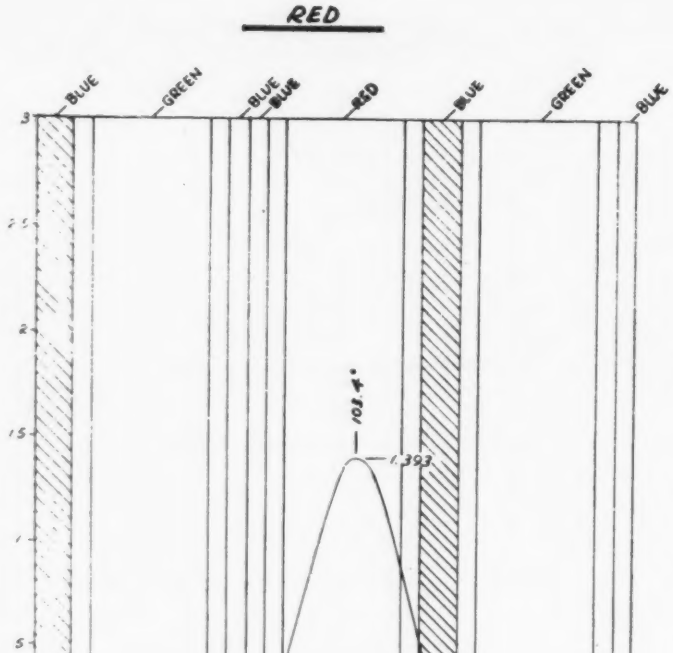



**Fig 4—Quadramatic beam decoding wave-forms indicating magnitude of color contamination of adjacent phosphor strips. The shaded area indicates the gated off portion of the switching cycle, where the beam is prevented from hitting the blue phosphor in order to obtain yellow presentation. Note that the green phosphor is not excited and that the blue phosphor excitation comprises less than two percent of the total illumination.**

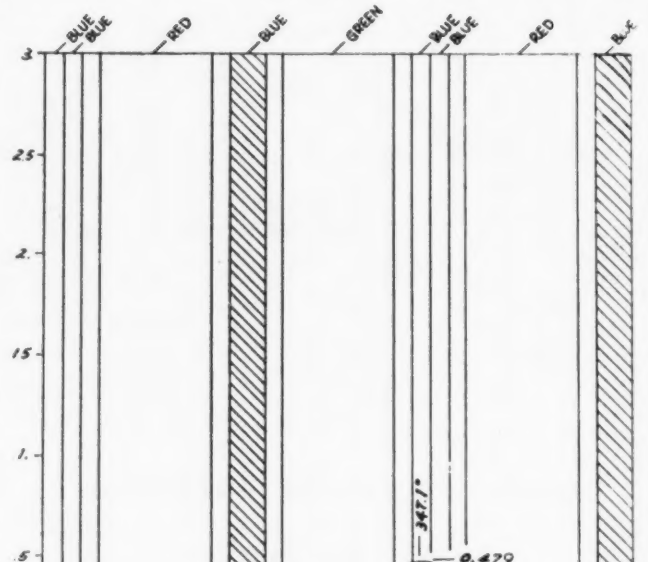



**Fig 5—Quadramatic beam decoding wave-form indicating beam current distribution and contamination of blue signal. Of the total beam current, 30 percent reaches the green phosphor and 6 percent the red phosphor. However, the blue phosphor has three times the luminous efficiency of either the red or green phosphors. Thus, the effective green contamination is only 16 percent and the red only 3 percent.**

Phosphor strip positioning on the screen is accomplished by means of a relatively new process employing photographic techniques. Substitution of a photo-sensitive aluminized plate for the phosphor screen produces a photo image of the raster pattern. The raster pattern thus obtained is reproduced exactly as it would be presented on the screen. Subsequent exposures from the master determine exact phosphor strip location for a given size screen. Phosphor arrays printed from such masters produce identical patterns in any number of similar tubes.

Width of the phosphor strip is made greater than the size of the electron spot, affording assembly and operating tolerances. To further assist in generation of pure colors, a narrow guard band, or blank space, is provided between adjacent phosphor strips. The complete absence of convergence problems inherent in a single gun tube contributes further to color purity.

One definite advantage of this technique for producing phosphor screens is that color cathode ray tube production problems are greatly reduced by allowing reasonable tolerances in phosphor printing, grid wire positioning, gun alignment, and assembly of tube components, while still achieving proper operation.

Commercial phosphors of equal persistance red, blue and green saturation, when used in conjunction with correct voltages, generate five color displays.

Where special applications require other than standard phosphors, any commercially available phosphor can be used. Radar display tubes are an example of an application where two color display would consist of a short and a long persistence phosphor. The short persistence phosphor would display the fixed presentation while the longer persistence phosphor would provide a picture of the target in another color.

## MECHANICAL DESIGN CONSIDERATIONS

Tube bulbs, or vacuum envelopes, for the Lawrence tube are made of metal, glass or ceramic, or combinations of these materials. Ceramic or metal tubes are particularly adaptable for industrial television uses where rugged construction and high temperature operation are commonplace.

Color selector grid wires, under tension of 50,000 psi or more, are anchored in an insulating medium of glass frit on a metal frame designed to withstand the high tension. Connections to grid leads are made outside of the frit seal and scanned area. Typical grids for a ten-inch tube would consist of 0.003″ diameter wire on 0.0125″ or 0.0156″ centers, producing 75 and 80 percent electron transparency respectively. Larger tubes have electron transparencies ranging up to 90 percent.

Since grid wires under high tension have a tendency to vibrate when switching takes place near resonant frequency of the wire, some form of damping may be required. Mr. Cone said that fine glass fibers pre-formed or preundulated and woven between the grid wires damp out incipient vibration. Although glass fibers appear quite fragile, he said, they have proved to be very durable. Glass for this use is especially chosen for strength and secondary emission capabilities. When hit by an electron beam, the fibers assume a positive charge, and thus erase their own shadow from the screen, he said.

Grid distance spacing from the screen is a function of the number of phosphor strips per inch. For 80 phosphor

strips per inch, which Cone said is a typical value, a ten inch tube with an over-all length of 20¼ has the grid 0.6" behind the phosphor screen. The grid wire diameter is 0.003" with a narrow guard band adjacent to each strip. There are no fundamental problems preventing single gun tubes being made in practically any size with grid and phosphor arrays ranging from 80 to over 120 per inch.

Spurious excitation of the wrong color phosphor by secondary electrons from the grid wires and primary beam electrons elastically scattered from the phosphors, glass plate and aluminum backing is minimized in the Lawrence tube by treatment of the grid wires to reduce secondary emissions and by coating the grid side of the aluminum with energy absorbing material such as boron, as well as by use of seeker voltage.

Sequential rather than simultaneous color presentation, also possible with the single gun, requires a high frequency switching rate. An external inductance resonated with the grid interelectrode capacitance forms very high-Q parallel resonant circuit at the 3.58 mc switching frequency, resulting in a very real power saving. Grid interelectrode capacitance is in the order of about 3000μμf. When this capacitance is resonated with the external inductance, high frequency sine wave switching occurs causing the electron beam to oscillate back and forth over the red, blue and green phosphor strips as raster scanning action takes place.

Color purity can be determined by analysis of electron beam current distribution over the phosphor areas. To obtain a perfectly accurate reproducing system, the electron beam should excite only the desired phosphor strip. Figure 3 indicates the magnitude of color contamination present in red due to the excitation of adjacent phosphor strips.

Blue has the most contamination of the primary colors. Figure 4 indicates the beam current distribution and contamination of a blue signal.

## APPLICATIONS OF COLOR DISPLAY TUBES

Mr. Cone pointed out that addition of multi-color display presentations to the conventional one color returns of current radar systems is an application of special significance in military aircraft operations. Pressures for the prompt recognition and correct interpretation of radar furnished flight information, he said, are substantially lessened when color coded returns are employed. To illustrate he cited examples of such applications.

The difficulty in differentiating between friendly and hostile aircraft in combat areas is largely resolved when enemy planes are reported, in conjunction with IFF or other identifying systems, in one color and allied planes in another.

Low altitude flying becomes far less hazardous when land masses below flight level are coded in one color and those above in a second.

Progress of moving aircraft across stationary land masses is easily traced when the fixed report is given in a background color and the traveling report in a sharply contrasted color.

Similarly, control of dense traffic patterns around major airstrips is expedited when approaching aircraft are displayed in one color and departing aircraft in another. Aircraft holding at different levels may also be coded in different colors to indicate odd and even altitudes.

One application of particular interest in these times of mounting dangers from air collisions, Cone said, is the presentation of data from radar-computer combinations giving the actual course in one color, a corrected course in a second, and the potential collision in a third.

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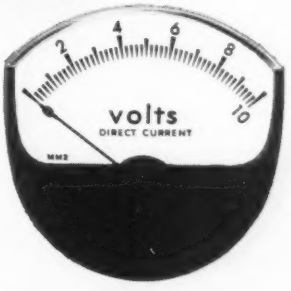


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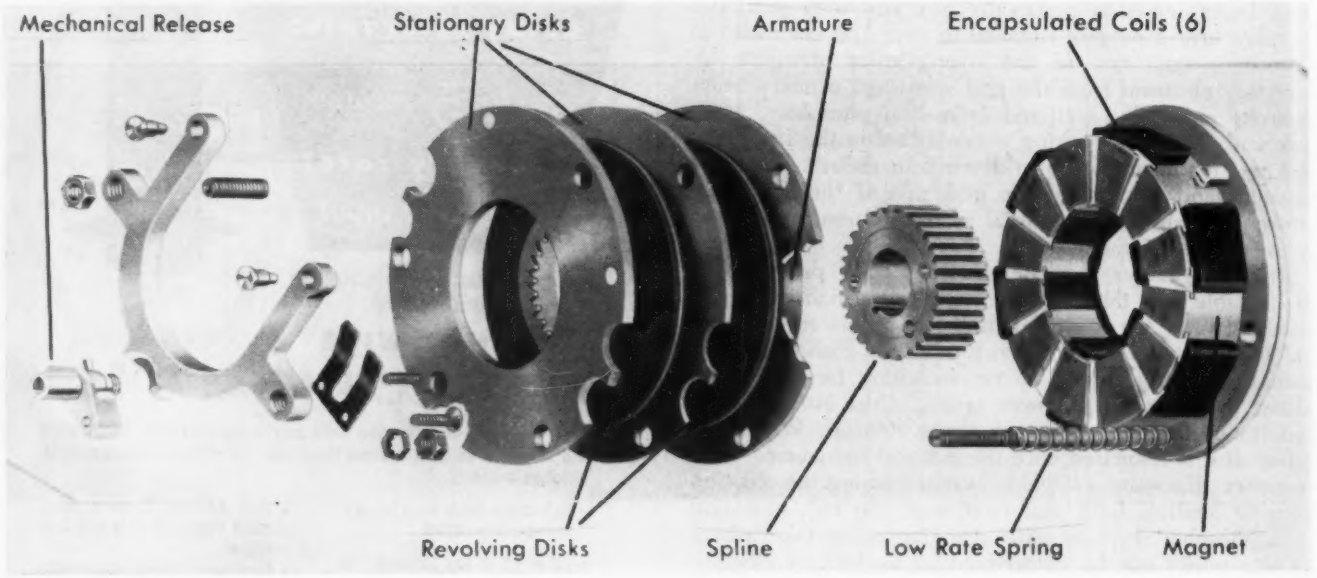


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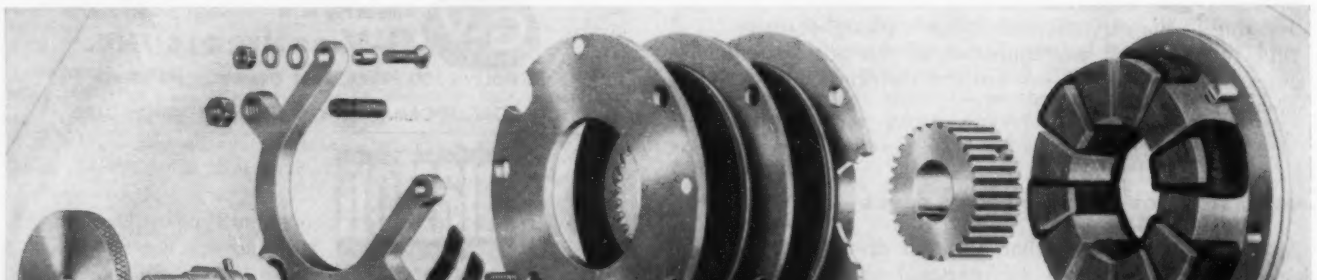


**Exploded view of electric brake indicates major areas of design changes: mechanical release assembly, spline and magnet and coil assembly.**

## ELECTROMECHANICAL BRAKE

### More Brake in Less Space with Lower Maintenance

Several years ago Star-Kimble's Industrial Motor Division (Safety Industries, Hamden, Conn.) began to keep a record of the performance of their electromechanical brake among their customers; object: to improve the performance of the brake by eliminating the most repetitive troublemakers.

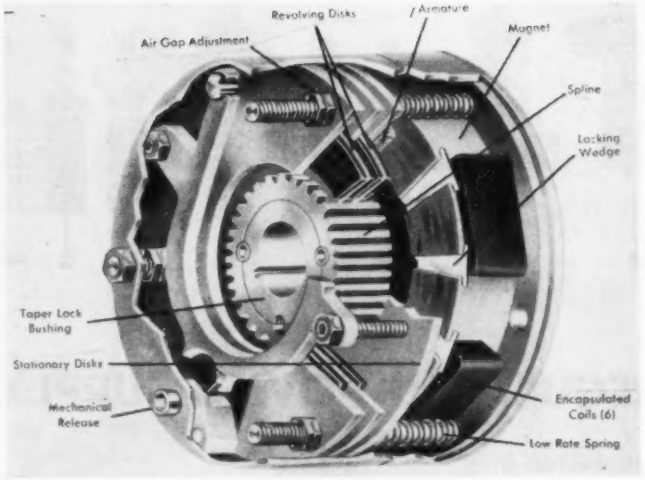
The study revealed that the greatest improvement could be made in these areas:

- Redesign to avoid faulty brake operation resulting from improper gap adjustment;
- Redesign to prevent coil burnout at high operating voltages;
- Redesign bushing and studs to prevent failures from rapid cycling or high vibration operations;
- Eliminate shading coil since they can become loose thereby creating excessive electrical noise;
- Redesign the brake flange to be mounted as an assembly on any standard C face so that it could be sold separately to other manufacturers;
- Reduce the cost of manufacture by designing one standard enclosed brake for continuous operation, thereby eliminating many existing variations including open and enclosed construction for both intermittent and continuous operation;
- And attempt to reduce the cost of standard parts by investigating the applications of new materials.

#### IMPROVEMENTS IN DESIGN

**Mechanical Release.** The redesigned mechanical release assembly consists of a cam system actuated by a single shaft. Turning the shaft advances the release pins on the lever toward the spring loaded magnet keeper. When the magnet keeper is displaced by the pins, the spring load is removed from the brake disks permitting the shaft to be rotated manually. The brake is reset automatically when the magnet is energized.

**Low-Loss Magnet.** Star-Kimble's magnet assembly represents a new departure in the design and assembly of magnets for electromechanical brakes. The assembly is a circumferentially wrapped core with twelve milled or punched slots in its front face. Six preformed coils assembled in these slots




**Using three instead of the usual four studs permitted the Star-Kimble designers greater control over the adjustment of the air gap between magnet pole faces and the armature. If the air gap is to be of uniform width, the face of the armature must be exactly parallel with the pole faces. This parallelism is easier to achieve with three studs, just as it is easier to level a three-legged stool than an ordinary chair. Readily accessible studs permit this adjustment, when required, to be readily made.**

(see exploded illus.) produce the equivalent of six E-magnets on a continuous core. A circumferentially wrapped armature completes the magnetic circuit. Advantage of this design is low power loss—80% less than in many conventional brakes. The design delivers a high pull-in force at large air gaps even when the line voltage is low, thus minimizing the need for gap adjustment. Use of six magnets provides greater flexibility for connection to various supply voltages; in addition, the continuous design makes it no longer necessary to specify different torque ratings for intermittent or continuous duty applications.

**Burnout Protection.** The air gap limiting design (see illus.) prevents the magnet from being energized continuously at excessive air gaps due to the inability of the coils to pull-in the magnet plate over a large distance; coils in AC circuits burn out under such conditions. As the keeper recedes from the magnet with brake lining wear, it finally engages fixed pins, preventing further widening of the gap. Air gap adjustment requirements become apparent as a result of gradual reduction in the braking effort resulting from the pins preventing the keeper from close engagement of the rotating disk. The design prevents improper gap adjustments from being made while the low rate springs keep the torque constant for the entire gap variation 0.125 inch change in spring compression for an initial compression of 1.5 inches. The gap limiter pins, by preventing the gap from exceeding a maximum tolerable value, prevent coil burnout resulting from the inability of the coils to pull in overlarge gaps developed from excessive lining wear.

### TORQUE STABILITY

The selection of a suitable lining material and pinion design control the performance of the brake with respect to torque stability and wear under hot and cold conditions. Requirements for a low cost lining material involved high friction coefficient, low wear and good thermal stability. Many different materials were tried, including sintered metal, woven asbestos and a number of different molded materials before a molded, impregnated resin was selected. The low cost pinion problem with suitable wear characteristics was finally resolved with the selection of a sintered metal pinion that requires no machining except drilling a tapped hole after molding.

William Penton, Star-Kimble's Chief Engineer, pointed out that the major advantages of the final design center on the special tape wound magnet which permitted coil power to be reduced low enough for a standard unit to be totally enclosed. Low coil power permits the brakes to be cooled by radiation so that proper operation is not dependent on the motor on which the brake is mounted. Sufficient magnet force is still developed in the diameter available between the stud ID and the pinion OD for sufficient spring force to develop the desired torque. Elimination of shading coils on both three phase brakes and single phase brakes eliminated problems in performance that could be caused by vibration.

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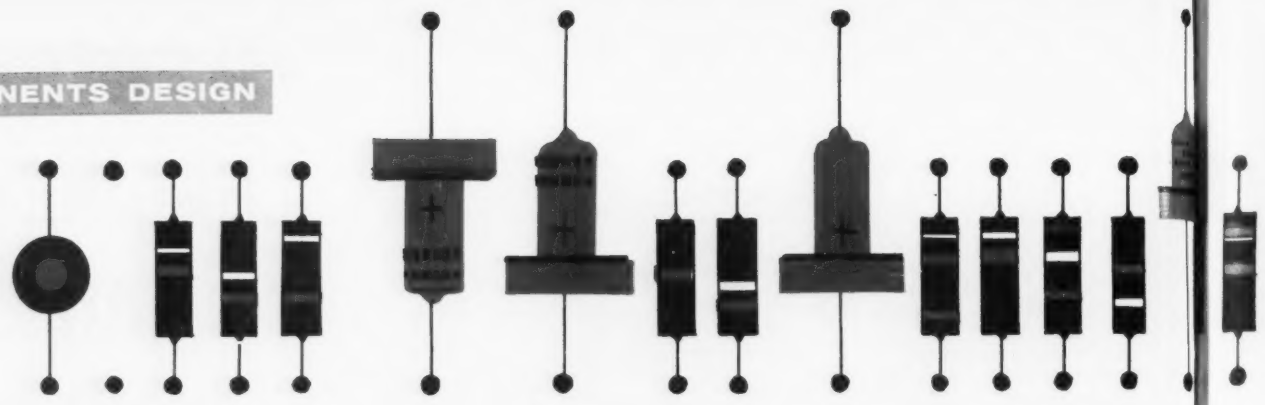


# THE TRANSISTOR REGULATED POWER SUPPLY AS A FEEDBACK CONTROL SYSTEM

**Clyde J. Norton and Milo F. Jamison, Jr.**

**Transval Engineering Corporation**

With the current trend toward more and more miniaturization and the increasing popularity of transistors in circuit applications where small size and ruggedness are prime factors, many old-time standard circuits and devices are being completely redesigned. Regulated power supplies are no exception, especially since the introduction of newer, higher power transistors.

The tendency, of course, is to attempt a simple replacement of vacuum tubes with their semi-conductor equivalents. This rarely results, however, in more than a first approximation of a successful design, and in the case of regulated power supplies. especially, a return to the fundamentals underlying the original circuit is imperative. The result is a significant improvement in the ultimate product and design coming off the production line. Regulated power supplies can be considered specialized types of feedback control systems, and a great amount of theoretical work has gone into development of such systems in the past few years. Application of this theory to power supply design is, therefore, one of the valuable adjuncts of transistor conversion.

A case in point is a better understanding of the pros and cons of using an a-c or a d-c signal to provide feedback information as a source of output voltage regulation control. In general, an a-c feedbcak system can result in more precise regulation of output voltage. This is true because of the possibility of providing a stable amplifier with higher gain and less drift. But there are times when simplicity and economy of design are more important than precision, and here a d-c signal is more than satisfactory. In both cases, however, a basic understanding of the fundamentals is the first step in the design process.

## FEEDBACK CONTROL SYSTEM DESIGN

As shown in Fig. 1, a regulated power supply consists of an amplifier which produces a varying impedance in series with the load, an output voltage sensing element, a reference voltage, and a feedback path with controlled characteristics. Any combination of various elements in these basic circuits can conceivably produce a workable power supply. Unfortunately, however, certain combinations produce over-all power supply circuits which are either unstable or very poor in regulation. As a general rule, the gains of both the amplifiers and the feedback circuit must be relatively high in order to produce a power supply with good voltage regulation. Since high gain inherently causes likelihood of undesirable oscillations in a feedback control system, special attention must be given to the balance between good regulation and system stability.

The gain of the amplifier shown in Fig. 1 is:

$$A = E_o/E_i$$

In this equation, voltage gain is represented by A, voltage introduced in series with the load is given as $E_o$, and input voltage to the amplifier is $E_i$. The amplifier serves as the forward loop element of a feedback control system.

The voltage value $E_i$ which is fed back in the basic power supply circuit shown in Fig. 1 is determined by the difference between the load voltage $E_L$, as attenuated by the output sensing element, and a reference voltage $E_{ref}$. This difference, or error, voltage is

$$E_i = E_{fb} - E_{ref}$$

where $E_{ref}$ is the voltage derived from a standard voltage source and $E_{fb}$ is the monitored load voltage attenuated by a resistance voltage divider to make its scale factor compatible with $E_{ref}$.

The voltage $E_o$, which is introduced in series with the load in order to regulate the voltage across the load, has the following relationship to the reference voltage:

$$E_o/E_{ref} = A/(1 - bA)$$

In this equation, which is the fundamental equation for any closed loop feedback control system, the factor b is a function of the regulated voltage across the load as defined by the following relationship:

$$b = \beta\ (E_{in} - E_o)$$

If A in the first of the two equations immediately above is considered to be of a value very much larger than unity, then the equation becomes the approximate expression:

$$E_o/E_{ref} = 1/b$$

or, rearranged algebraically in order to express the controlling voltage $E_o$ in terms of the reference supply,

$$E_o = 1/b\ E_{ref}$$

In this last equation, since $\beta$ is fixed by the values of the resistance network

# Here's how to design transistorized power supplies that function accurately under severe ambient conditions

which senses output voltage, the factor b may be thought of as a constant times output voltage variation. The output voltage variation is, of course, due to two factors: (1) line voltage changes, and (2) load variations. Therefore, the regulated power supply has been defined in terms of the only two operation variables which normally occur—line voltage changes and load changes. The other parameters involved in the operation of the instrument are all set in design of the circuit.

These control system equations and concepts are rigorously correct, and, if interpreted in the right manner, can aid immeasurably in the efficient design of dependable, stable transistorized regulated voltage supplies. Of course, the actual characteristics of the complete power supply are succinctly described by the following equation which relates regulated output voltage to line voltage:

$$\frac{E_L}{E_{in}} = \frac{1}{1+\beta A\ [1-(E_{ref}/E_L)]}$$

Also, it can be easily noted from the above equation, that the following relationship is true:

$$E_o = E_{in}\left\{\beta A\,[1-(E_{ref}/E_L)]\right\}$$

or, in other words, since β, A, and $E_{ref}$ are fixed, $E_o$ varies due to (1) the input voltage, $E_{IN}$, and (2) the load voltage, $E_L$, which is the value that is being regulated in the first place. A quick first approximation to the amount of voltage change that must be introduced by a series regulator transistor can be derived from this last expression by substituting anticipated line voltage variations and load variations into the equation.

In all the above equations, the voltage value $E_o$ is achieved by introducing a deliberate controllable impedance in series with the load. And so it is that an amplifier with variable impedance characteristics becomes an important factor in the design of a transistorized regulated power supply.

## FORWARD LOOP AMPLIFIER

Transistor amplifier circuits in general consist of circuits which provide each transistor with correct impedance loads for the base, collector and emitter in conjunction with an arbitrary bias voltage at each of the three transistor terminals. If the base-emitter bias voltage of the transistor is changed, then the collector-emitter impedance of the transistor acting as a series element changes. This physical effect is used in the design of a transistorized regulated power supply. Part of the output voltage of the power supply is continuously monitored and altered to provide a bias voltage at the terminal of a transistor acting as a forward loop amplifier. The result is that when the output voltage varies due to load or line variations, the bias on the forward loop amplifier transistor changes in such a manner that the output voltage returns to its correct and previous value. In order to sense that the output voltage has strayed from its desired value, a reference voltage is established within the regulated power supply. This reference is usually generated in semiconductor power supplies by using either a standard voltage cell or the constant voltage characteristics of a Zener diode.

Fundamentally, that is the complete story of what happens in a transistorized regulated power supply. The factors which make for high quality supplies are the details of how these fundamental tasks are accomplished.

## D-C FEEDBACK SUPPLY

Figure 2 shows the schematic diagram of a transistor circuit that provides excellent forward loop amplification with changes in output voltage easily accomplished by means of a control voltage applied to the base. In this circuit,

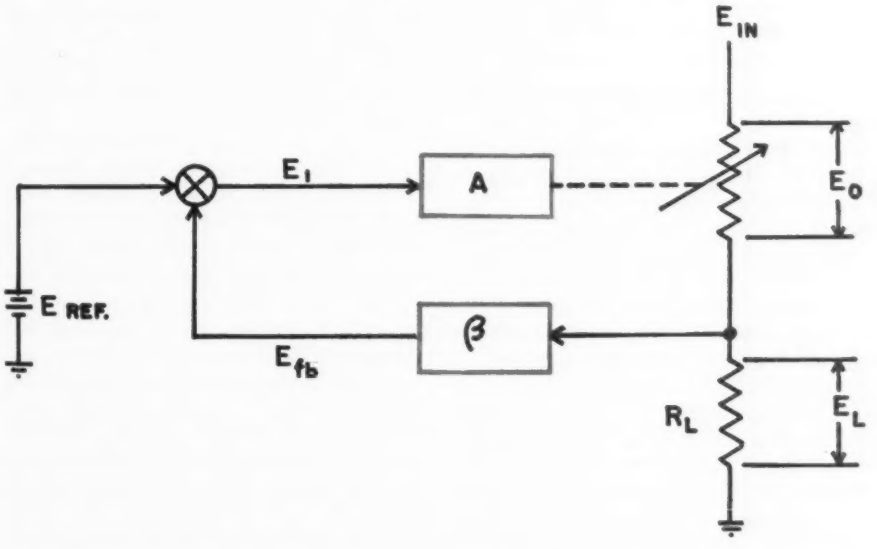



Fig 1—Basic block diagram of transistorized regulated power supply. The internal reference voltage $E_{ref}$ is compared to a feedback voltage $E_{fb}$ which is derived from the output voltage of the power supply. The feedback network, represented here by $\beta$, consists of a voltage divider and an amplifier. The forward loop amplifier $A$ controls the impedance in series with the load to provide precise regulation of the output voltage with varying current conditions in the load.

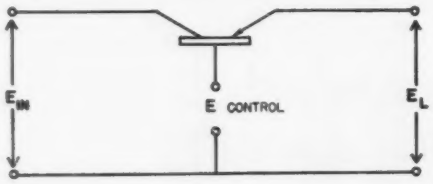
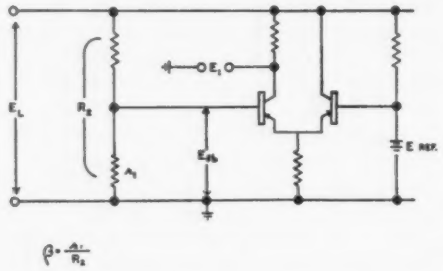



FIG 2—Control of impedance in series with the load of a regulated power supply made up of transistor circuitry is accomplished by the amplifier shown. The input voltage, $E_{in}$, is fed through a series amplifier to the load, resulting in load voltage, $E_L$. The series impedance of the amplifier is controlled by a voltage in series with the transistor base lead. This base voltage, which, in effect, acts as a bias, comes from the feedback loop of the power supply, having originated as a sampled portion of the output voltage.




$$\beta = \frac{A_1}{R_2}$$

FIG 4—Schematic diagram shows how a d-c difference amplifier consisting of two transistors is used to compare the reference voltage in a transistor regulated power supply to a portion of the load voltage. The amplified error, or difference voltage, $E_1$, is used, in turn, to control the forward loop of the regulator in order to control the output voltage, $E_L$. The difference amplifier configuration has many advantages over single-ended amplifications, foremost of which is nearly-complete temperature compensation.

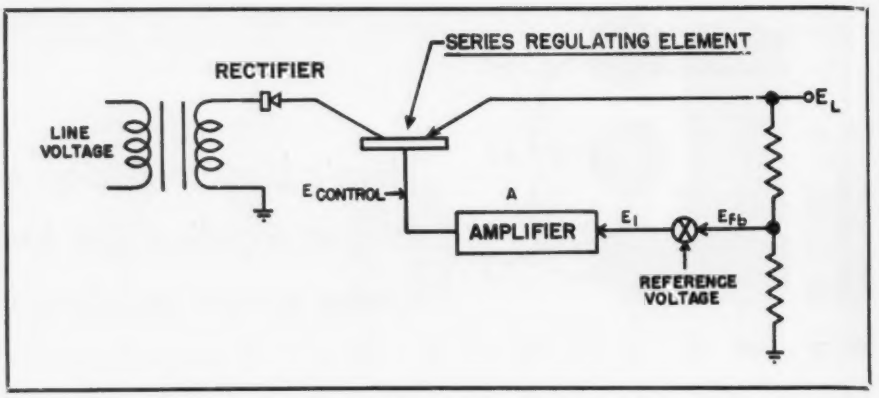



FIG 3—Generalized schematic of transistorized regulated power supply.

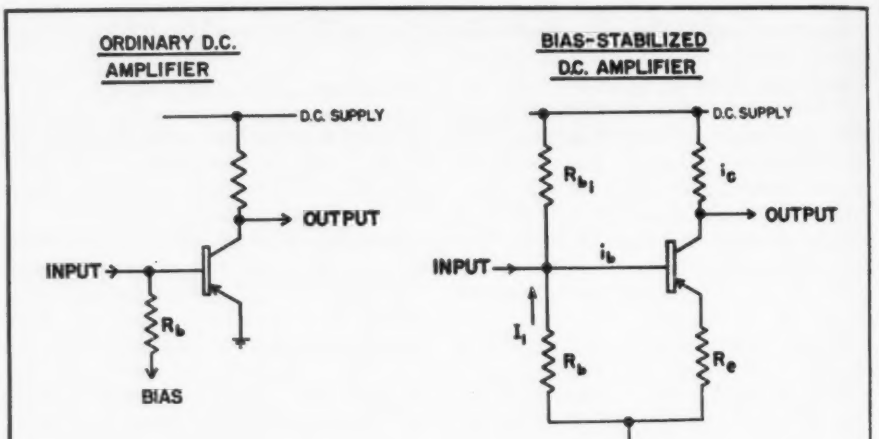



FIG 5—Schematic comparison of ordinary d-c amplifier and bias-stabilized d-c amplifier.

the feedback voltage $E_{fb}$ is a d-c voltage.

The d-c feedback voltage applied to the forward loop amplifier of Fig. 3 is derived from the circuit element that senses output voltage variations. This does not mean, however, that the voltage must be fed via a direct wire from the output voltage divider into the forward loop amplifier. Indeed, an amplifier and/or attenuator circuit is the rule rather than the exception in the path between the output voltage divider and the forward loop amplifier.

An attenuator circuit between the output voltage divider and the forward loop amplifier results in a low feedback loop gain and consequently a relatively poor output voltage regulation. For this reason, it is usually desirable to provide amplification rather than attenuation in the feedback circuit. This amplification is particularly desirable in view of the fact that the output voltage sensing device is usually an attenuator by its very physical nature. Hence, an amplifier which simply restores the feedback voltage to the nominal value of the output voltage is not an element that introduces very much amplification to the feedback loop of the over-all voltage regulator system.

Figure 4 shows another transistor circuit that serves as an excellent means of comparing monitored output voltage to a reference source. In this case, the amplifier is a configuration of two transistors which act as a difference amplifier. The difference amplifier has several advantages over a single-ended configuration. One of the biggest advantages is the fact that temperature variations which would normally vary the gain of a single-ended amplifier cause very little, if any, variation in the characteristics of the difference circuit. This fortunate circumstance is due to the fact that the two transistors are connected out of phase with each other; the result is that any positive voltage change in one transistor is matched by a negative voltage change in the other when temperature changes. The cancellation of temperature effect is not complete due to variations in individual transistor characteristics but such a considerable reduction of ill effects is created by the difference circuit configuration that only slight compensations need to be made in the circuit to provide for wide swings in ambient temperature conditions. These compensations may be in the form of temperature-sensitive resistors, such as thermistors, which change their resistance value as a function of ambient temperature. This difference amplifier provides a superlative means for comparing the power supply output voltage to a reference source.

Actual values of gain in the feedback circuit vary over wide ranges, depending upon the particular power supply in question. When the feedback gain desired is relatively low in value, a d-c amplifier, preferably a difference circuit, works quite well. Besides being relatively insensitive to temperature variations, the difference amplifier provides the advantage of presenting a nearly constant-current condition through the common emitter resistor in the face of input signal variations. This makes for extremely stable operation of the amplifier.

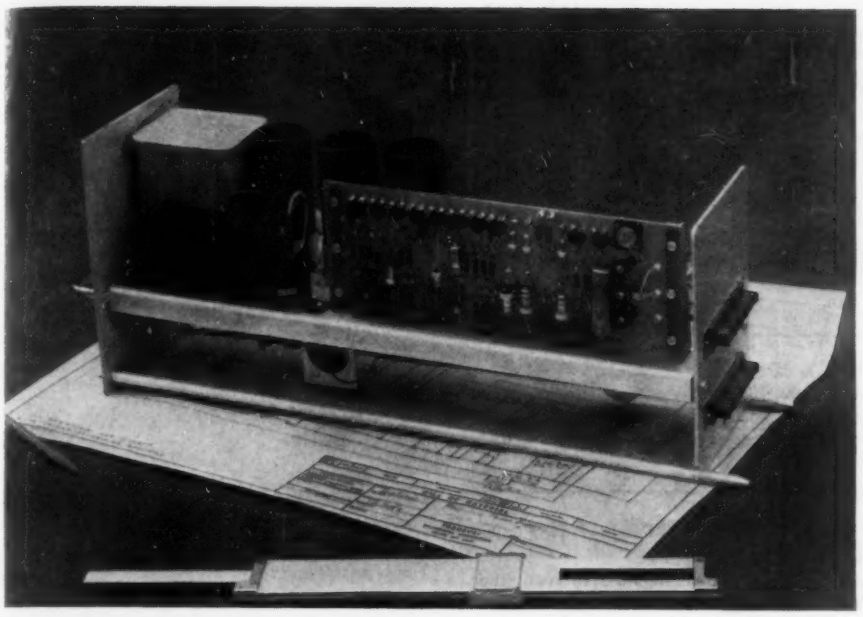


Fig 6—This high-precision transistorized power supply delivers 4 amperes at a fixed value of 10 volts d-c. The supply has been carefully engineered to make optimum use of the light-weight, rugged characteristics of power transistors.

### TRANSISTOR DIFFERENCE AMPLIFIER

Transistor amplifier circuits are plagued by changes in transistor characteristics resulting from severe changes in current through the transistor. Any circuit that tends to keep a constant current through a bias-determining element in a transistor amplifier is desirable. The d-c amplifier shown in Fig. 5B accomplishes this function. A voltage divider consisting of $R_b(_1)$ and $R_b$ is established so that a large current $I_1$ flows. This current $I_1$ is very much greater than $i_b$. Small changes in $i_b$ with temperature do not affect the bias voltage at the transistor base to any appreciable extent. Addition of emitter resistor $R_e$ adds degenerative feedback and enhances the stability of the circuit even more.

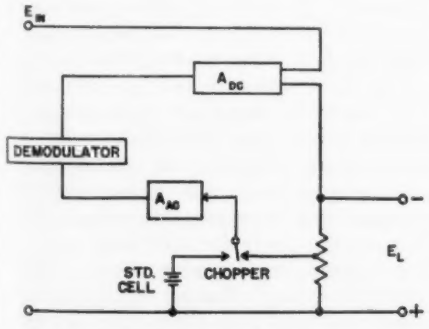



Fig 7—Simplified block diagram of an a-c feedback, transistorized power supply. The electromechanical chopper continuously compares the reference voltage within the power supply, provided by a standard cell, to a sampled portion of the d-c output voltage. The output of the chopper is an a-c voltage amplified by the transistor circuit $A_{AC}$. This amplified a-c voltage is subsequently demodulated and fed to the forward loop amplifier, $A_{DC}$.

### A-C FEEDBACK SUPPLY

When higher precision in regulation is needed; for example, a regulation of 0.01 percent, a power supply such as the one shown in Fig. 6 can make use of a-c feedback instead of d-c. This is accomplished by the circuit shown in Fig. 7. As the diagram indicates, the output voltage is sampled, as in the case of the d-c feedback power supply, via a voltage divider. This feedback voltage is then modulated at line frequency by means of an electromechanical chopper. The modulated (a-c) voltage is then amplified and demodulated in turn. The demodulated voltage, which is again a d-c voltage, but of a larger value than before, is applied to the forward loop amplifier, in much the same manner as was the case in the d-c feedback supply described above.

The major difference between the d-c feedback scheme and the a-c feedback scheme is that higher feedback loop gains can be more readily accomplished with the a-c scheme.

### FILTERING WITH ZENER DIODES

Since the basic system equations discussed earlier hold true for signals of all frequencies, it sometimes happens that high frequency signals get amplified to the extent that the output voltage becomes greater than the input voltage, or perhaps feedback voltages in phase with the input voltage reach sufficiently high values to cause oscillation through fulfillment of the Barkhausen criterion. To avoid this unstable condition in d-c power supplies, it is good practice to include filtering in the circuit. A filter that shorts out in lieu of the capacitor across a voltage to be filtered. It happens that a connection of a semi-conductor diode all high frequency voltages to ground is the best solution. A simple capacitor connected in parallel across the output is one good way to accomplish this function.

Another equally effective solution to the general problem of filtering is the Zener diode can be used effectively to perform the filtering action at the same time that it is performing a voltage reference function. Such diodes are used in the power supplies pictured here to provide filtering in the bias sources within the power supply. Considerably smaller units result when these Zener diodes are used instead of conventional RC and LC filters.

### SPECIAL FEATURES OF TRANSISTOR POWER SUPPLIES

Among the several features of transistorized power supplies that deserve special mention is the possibility of obtaining an extremely low output impedance. An output impedance of two ohms is not uncommon in power supplies constructed of transistors. Values as low as $50 \times 10^{-6}$ ohm (fifty micro-ohms) have been achieved in the precision supplies pictured here.

Less than one millivolt of ripple is obtained at the output terminals of the power supply pictured in Fig. 6; the normal factor of 0.01 percent is achieved by careful circuit design in conjunction with extremely high gain amplifiers.

Zener diodes used to provide the reference voltage in many transistor power supplies can be obtained not only possessing very good temperature and stable voltage characteristics, but also in such small physical dimensions that they take up an extremely small amount of space. In addition, they draw such a small amount of current that their effect on over-all power considerations in the circuit is practically negligible. Standard reference cells can be used in lieu of diodes, but as a general rule, the Zener diodes perform admirably well.

Of course, the obvious advantages of transistors, such as the absence of filament current, small size, ruggedness, and ease of mounting, apply in the case of power supplies as in all other circuits. High frequency response characteristics of the transistors, although quite important in many circuit applications, are not factors to be unduly concerned about in the design of transistor power supplies. In short, transistors really come into their own in the case of power supplies. Figure 8 illustrates advantages of compactness

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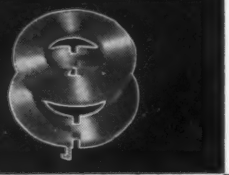

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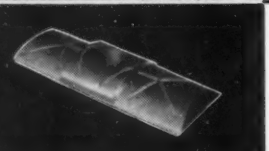

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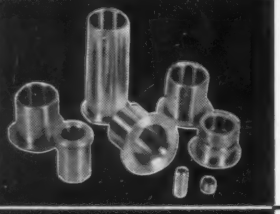

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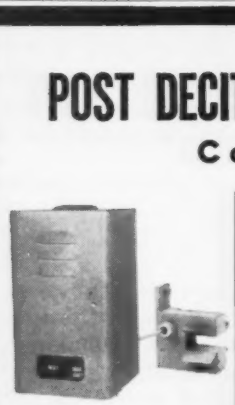

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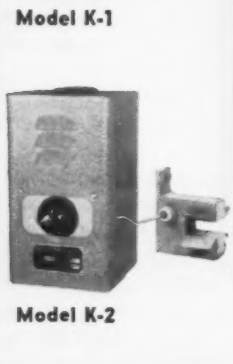
**Model K-1**
This is a general purpose photoelectric control whereby the interruption of a light beam closes a relay which, in turn, can be used to activate an external circuit.

**Model K-2**
The "K-2" control differs from the "K-1" in that the output relay will not energize for each interruption of the light beam, but only if interruptions cease. Useful for detecting stoppage "flow".



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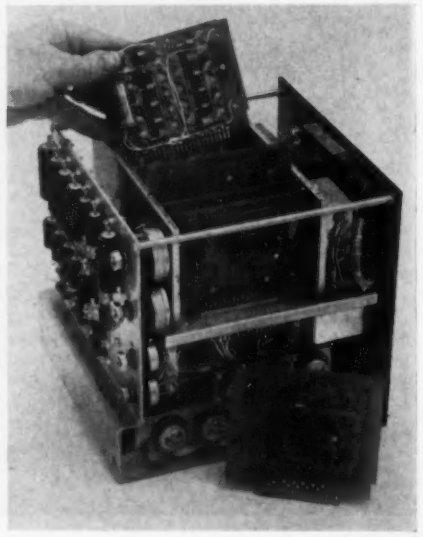

FIG 8—Modular construction of transistor circuits in regulated power supply manufactured in quantity by Transval Engineering Company aids in speedy replacement of parts in field in the event the equipment experiences a malfunction. Actually, damage resulting from everyday use is small, because of special overload and overvoltage circuit protection designed into the precision power supply.

and modular construction made possible by transistorized circuits.

### CIRCUIT PROTECTION AGAINST SURGES

Protection of transistors against sudden surges of current, which would destroy the components or change their operating characteristics drastically, is provided in the power supplies pictured by a unique scheme.

The scheme uses a circuit which Transval Engineering Company has patented and calls a "magic square." The magic square is connected in the circuit in series with the forward loop amplifier. As soon as load current begins to increase beyond its nominal rated value because of changes in load impedance, the magic square changes the apparent impedance in the power supply forward loop so that less current is allowed to flow. In essence, the circuit can be thought of as apparently violating Ohm's law. As the output voltage increases, or as the load impedance decreases, the current decreases. This effect is carried out to the extent that practically no current flows when a short circuit is imposed across the output terminals of the power supply. The magic square circuit consists of a transistor amplifier connected in a bridge circuit.

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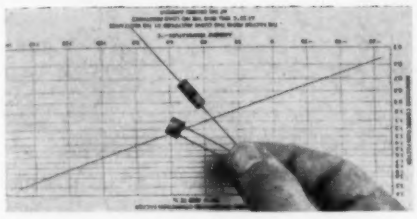
### Memory Amplifier

This latching type amplifier, less than 2/3 cu. inch in volume, with ability to control power into a load consists of an amplifier and bistable circuit. Upon application of a 50 millivolt trigger full supply is applied to the load. The amplifier takes 2 input pulses between which power is alternatively applied or removed from the load. With low current standby in "Off" condition, it draws no more than 1.5 milliamperes. The memory amplifier includes four subminiature transistors and achieves density of 100,000 parts/cu. ft. Operation is stabilized in ambient temperatures from −25° to +50° C. The amplifier will control up to 20 times the load required during standby condition and is suitable for use in a power transistor or additional relay to control larger amounts of power. M. F. Electronics Co., New York, N. Y.

Circle No. 144 on Inquiry Card



### Temperature Sensitive Silicon Resistor

A new silicon resistor with a 0.7%°C positive temperature coefficient of resistance responds to an increase in temperature with an increase in resistance that rises rapidly along a stable, retraceable characteristic curve.

Because of this large positive temperature coefficient, the silicon resistor, called a Sensistor, is expected to have wide application as a temperature compensating device in miniaturized amplifiers, servos, computer switching circuits, magnetic amplifiers and power supplies. It is also expected to be ideal for use as a temperature sensing element for automatic controls and other precise temperature indicating applications. Previous temperature sensing devices, such as thermistors, have been characterized by a decrease in resistance with a rising temperature.

There are two configurations: TM ¼ is an axial lead molded device which is linearly derated at full load from 100°C to 150°C, TC 1/8 is encased in a TO-5 round-welded package and is derated linearly at full load from 125°C to 200°C. Both units are immediately available in commercial quantities in standard resistance ratings ranging from 100 to 1000 ohms at 25°C. Texas Instruments, Inc.

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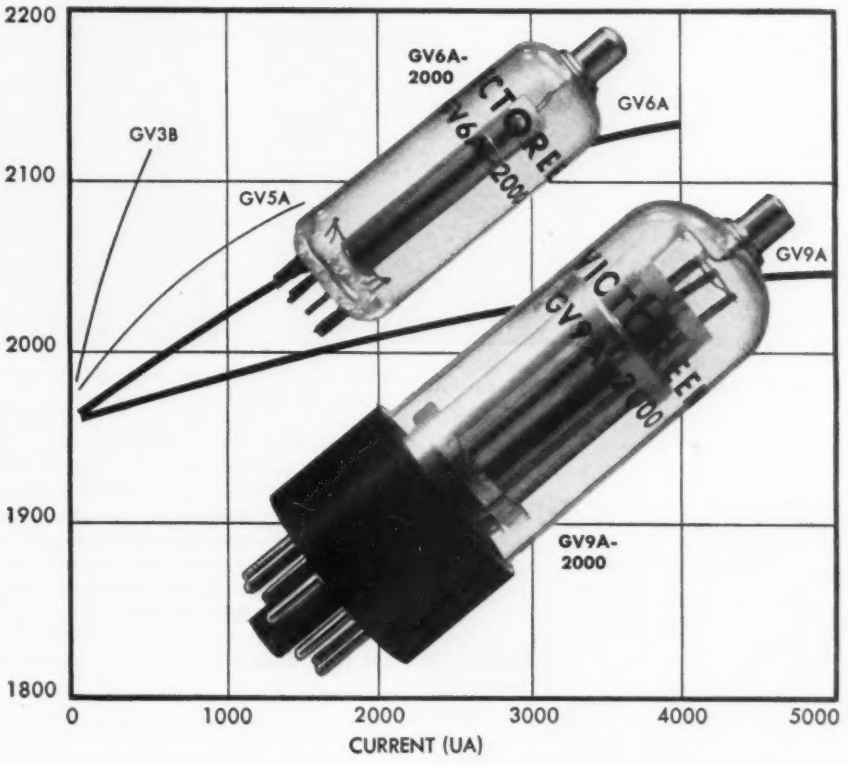


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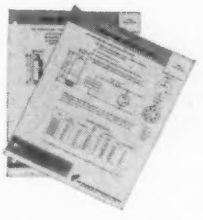

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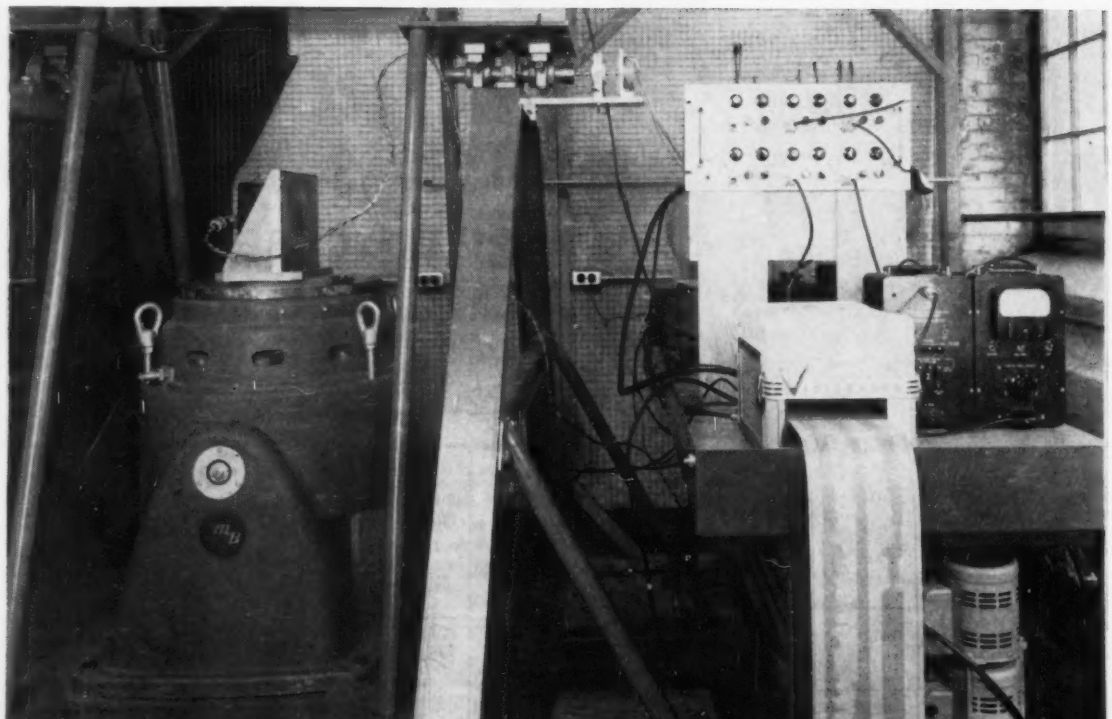

**FIG 1-Detroit Controls Systems for vibration testing of a turn rate transmitter under simulated operating conditions. At the left a CIO electrodynamic vibration exciter made by the MB Manufacturing Company, New Haven, Conn., is secured permanently to the pendulous platform and, although weighing about 900 lbs, is swung through arcs as large as 60° as it vibrates the transmitter specimen in a fixture on the exciter table. Electrical outputs of the three gyro amplifiers in the transmitter package are fed into an external multi-channel d-c amplifier and then to a direct-recording photographic oscillograph (right). The angular rate, impressed on the turn rate transmitter as the exciter swings back and forth on the pendulum (the input signal to the gyros), is sensed directly at the axis of the pendulum (upper center). A potentiometer on the end of the shaft is connected to produce an angular rate signal, which is then fed into the amplifier and recorder for recording on a separate channel of the strip chart.**

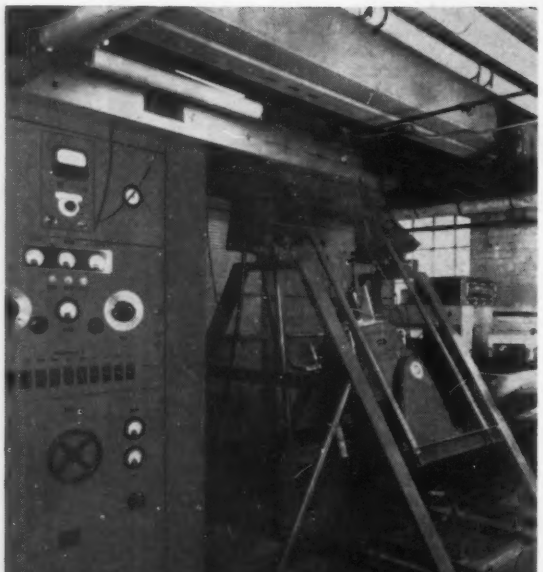

**FIG 2—MB T51M electronic power supply for the vibration exciter.**

## DYNAMIC TESTING

### Gyro Package Shakedown

Recently the Environmental Test Group of the Control Engineering Unit, Detroit Controls Corp., Norwood, Mass., was required to develop an air worthiness test for a turn rate transmitter, which included three gyros for indicating rate in yaw, pitch and roll. The purpose of the test series as described by George K. Haycock, environmental test engineer, was to evaluate an integral orifice-plunger damping mechanism and other design functions over temperature ranges expected in missile flight by observing gyro output changes under various conditions. Vibration tests were to be performed with the gyros and the turn rate transmitter both functioning and not functioning and at room temperature, +250°F and −65°F. The tests were to be performed with the turn rate transmitter in three axes.

The results of the vibration tests were required to be in the form of curves for peak gyro output (in percent of full-scale) due to impressed vibration frequency from 5 to 500 cps. Nine separate curves were then necessary, one for each gyro (yaw, pitch and roll) in each of three positions of the turn rate transmitter.

The minimum acceptable standard by the airframe manufacturer was that gyro output due to impressed vibration in the range 5 to 500 cps was never to exceed 0.5 of 1 percent of full scale output. Thus the air worthiness tests were actually to evaluate the efficiency of the gyro damping mechanism in subduing resonant peaks at the natural (and harmonic) frequencies in the gyro and transmitter assembly.

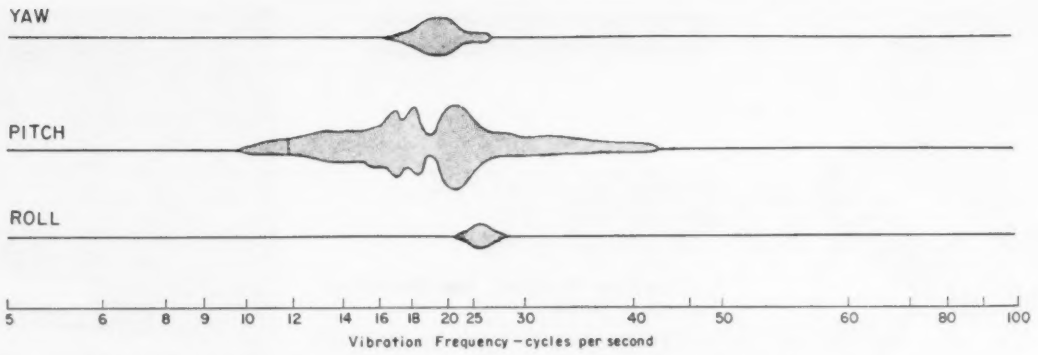


**FIG 3—Typical resonant responses of gyros under vibration but with no ratio input.**

## PENDULUM-EXCITER TEST SYSTEM

The arrangement of the platform pendulum and vibration exciter in Fig. 1 was selected as the most practical and least expensive system for accurately and quickly testing the turn rate transmitters in compliance with the air worthiness specification.

The pendulum structure was designed so that for the weight of the vibration exciter the period of the swing is two seconds (a frequency of 0.50 cps). The pendulum is energized simply by pushing it out to an angle from the horizontal that will produce the required initial rate level and releasing it. Figure 3 shows the pendulum and exciter at about 25° off horizontal during a free swing. The angular rate as the pendulum swings free is approximately a sinusoidal function. Angular velocity of the pendulum at the bottom of the swing, where it is maximum, corresponds to the maximum rate specified for the test. An approximate rate of decay of the pendulum swing is also indicated in the procedure.

## VIBRATION TEST PROCEDURE

- *Recording gyro input* without applied vibration. Initially set the pendulum in motion at an amplitude that will produce a maximum full rate input to the gyro. Damp the pendulum so that the input rate decays to 20 percent of full value in about 20 cycles of the pendulum. Record for a total of 150 cycles until the rate decays below 5 percent. Follow this procedure with the turn rate transmitter in each of three positions on the test fixture, so that each of the three gyros is in turn subjected to the angular rate of the pendulum. Since this test is performed with no applied vibration, the recorded output tracings on the strip chart for the yaw, pitch and roll gyros represent the input rate function alone.

Recorded signal output from more than one gyro for each position of the turn rate transmitter indicates that the three gyros are not orthognally oriented or that the transmitter is not properly positioned. The major purpose of the first series of tests is to remove any crosstalk by adjusting the positions of the gyros.

- *Resonance search.* Record the output noise of the three gyros in each of the three axes by slowly varying the frequency of the vibration exciter from 5 to 500 cps with no input rate (with the pendulum still). Recently the test limit has been extended to 2000 cps, the frequency limit for the chart recorder (the exciter may be used up to 3000 cps). This procedure is repeated for each gyro with the equipment stabilized at room temperature, +250°F and at −65°F. Then vibrate the transmitter in each axis at an appropriate frequency specified by the airframe manufacturer for the following periods: (a) 130 minutes at room temperature, (b) 25 minutes at +250°F, and (c) 25 minutes at −65°F. During this series of tests, release the pendulum with a first-cycle maximum rate of 50 percent of full turning rate.
- *Tests in operation under most severe vibration.* Repeat the test procedure given in Step 1 with the C10 vibration exciter producing an acceleration level of 3 g along that transmitter axis and at that single vibration frequency which the resonant search has shown to result in the highest gyro noise output.
- *Combined temperature - vibration.* Repeat the tests in Steps 1 and 3 with the specimen transmitter temperature-stabilized at +250°F and −65°F.

The cabinet on the left in Fig 2 is the MB T51M electronic power supply for the vibration exciter. Operation of the exciter both during the resonance search in Step 2 and single-frequency test in Step 3 is controlled entirely at this point.

Controlled temperatures in the range from −65°F to +250°F are established in a portable environmental chamber designed for easy installation over the exciter table. The chamber has 2-inch-thick insulation walls covered with impregnated glass cloth and has a removable top.

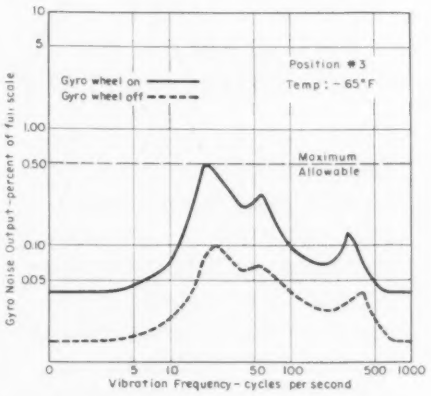


**FIG 4—Gyro noise output due to vibration determined from tracings of gyro output for peak angular rate input of 5 percent of full scale.**

## TYPICAL TRACINGS AND RESPONSE CURVES

The trace envelopes in Fig. 3 are typical vibration tests on a turn rate transmitter with no rate input (stationary pendulum). While the exciter frequency range for the test was 5 to 500 cps, the observed resonant response of the gyros is limited to frequencies between 10 and 40 cps. It is evident that the transmitter package is so oriented that the signal output of the pitch gyro is most affected. Thus, if the transmitter is most sensitive to vibration in this orientation, the vibration tests in Step 3 above would in this case be run at about 20 cps.

When the pendulum swings as the transmitter is excited, a vibration response like that in Fig. 3 is superimposed on the 0.50 cps sinusoidal variation of the rate output. Because the signal amplitude due to vibration is so small, less than 0.5 percent of full scale, it is accurately measurable on the strip charts only when the rate input is comparatively small. In Fig. 4, gyro noise output due to vibration has been determined from tracings obtained with a peak rate input of 5 percent of full scale.

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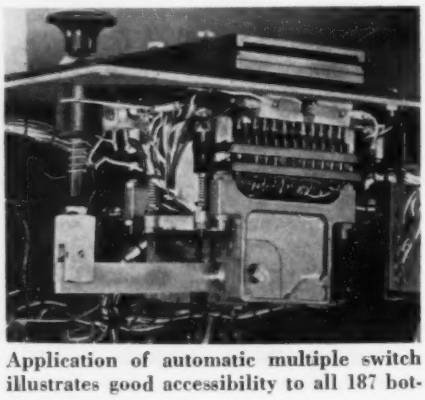
The new design combines simplicity and ruggedness with relatively high current carrying capacity and unusually low contact-to-pin resistance.

The single-pole single-throw floating contacts are housed in a sandwich design that allows individual connection



**Application of automatic multiple switch illustrates good accessibility to all 187 bottom contacts.**

to all contacts on the bottom plate. Connection to approximately 60 individual top contacts is provided as a normal maximum to simplify wiring by use of top contact strips. These contacts are generally wired to a terminal strip for neatness of access. A rectangular arrangement of 17 by 11 contacts occupy the switch deck area of three by five inches.

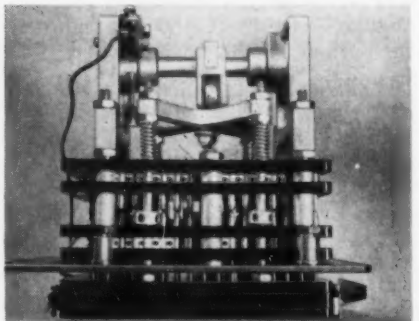
A selected pre-punched vinyl code card inserted into the unit operates a momentary control solenoid trip mechanism to actuate all desired contacts simultaneously. The code-cards are pre-punched on the basis that the absence of a hole provides a contact actuation. If the switch is accidentally actuated without a card, no contact is made and there is no possibility of circuit damage due to overload. A positive alignment feature insures that the card actuates the switch mechanism only when the card is in proper position. Vinyl material is able to withstand almost unlimited use and has proved to be the most reliable code-card material.

**Switch may be operated manually. A card with holes punched for every contact position is used to actuate the micro-switch momentary control-solenoid trip device, and a plastic probe can then be used to manually close all desired contacts.**

To open all contacts and release the code card, a top lever cam is depressed to energize a spring type actuating mechanism for the multiple switch operation.

It is unusual to find switching problems that exceed the variables allowed in the Hickok Cardmatic switch, and unlimited switching arrangements can be accommodated through multiple grouping of the basic switch. The Hickok Electrical Instrument Co., Cleveland, Ohio.

Circle No. 111 on Inquiry Card



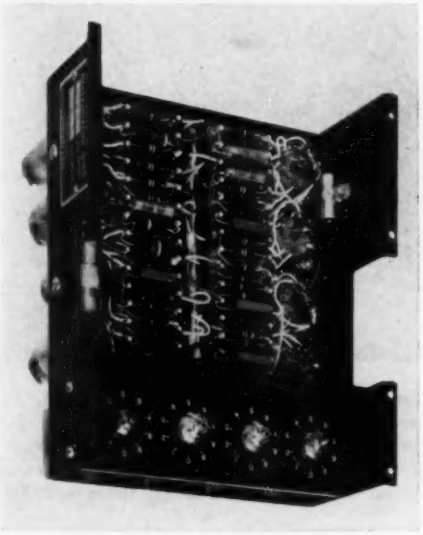
**The heavy cast and machined parts of the mechanical actuating mechanism allows use of husky operating torque to make possible heavy contact pressures which with the self-cleaning wiping type contacts, provide unusually low contact resistance.**

### Miniature Digital Timer

Miniature 4-decade digital timer, simple to operate and able to withstand severe environmental conditions, has time resolution of one millisecond and maximum indicating time interval of 9.999 seconds. Glow transfer tubes are used as decade counters and indicators. Pulses from a 1000 cps tuning fork feed a gated amplifier which controls miniature start and stop thyratrons.

The simplicity and small size of the unit is due largely to the thyratron

gate controlled circuitry which reduces the normal requirement of ten triodes to two miniature gas filled tetrodes. The timing pulses from the low frequency 1000 cps tuning fork oscillator and squaring amplifier use two twin triode tubes. No frequency dividers are used since the 1000 cps timing frequency is counted directly. The counting unit also employs only two twin triodes for driving all four glow transfer decade counting tubes. Consequently the unit requires only eight



tubes in addition to the four counter tubes.

A pulse defining the beginning of an interval triggers the start thyratron, whereupon the gated amplifier passes pulses to the counting unit. A pulse defining the end of the measured interval triggers the stop thyratron, closing the gate. The registered count is the elapsed time in milliseconds. A manual reset switch returns all counters to zero, at the same time resetting the thyratron gate control tubes. Voltage stability is assured through the use of a ruggedized glow tube regulator.

The timer was designed to mount behind a panel having a 1⅜ by 4 inch cutout for viewing the decade counters. In spite of the unit's reduced overall dimensions, space has been reserved within the chassis for operating controls such as start-stop signal input attenuators, polarity selector switches, and reset switches. Although designed for 24-28 volt operation, high voltage supplied by a 12 watt transistorized DC converter can be used with a conventional power supply using a 60 cycle per second 117 volt line voltage. The company states that the unit can be recycled many thousands of times without the maintenance usually associated with the electromechanical stop clock timers it was designed to replace. Erie Resistor Corporation, Erie, Pa.

Circle No. 128 on Inquiry Card.

Nonlinear ACEPOT shown actual size.

# ACEPOT®

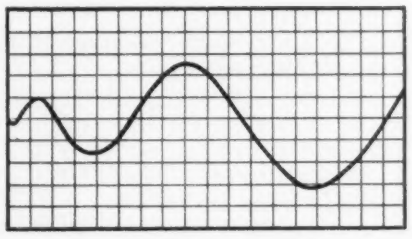
## PRECISION, WIRE-WOUND

## NONLINEAR POTENTIOMETERS

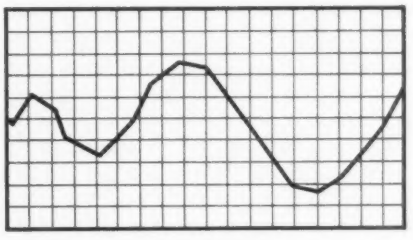
### 0.25% terminal conformity *without padding resistors*

A potentiometer without padding resistors produces a smooth output function curve as opposed to a stepped function curve when padding resistors are used. With the addition of padding resistors there is also a corresponding decrease in reliability and accuracy since each padding adds a pair of critical tap-offs to the delicate wire windings.

ACEPOT nonlinear potentiometers have terminal conformity to 0.25% without padding resistors. Desired output function is achieved by use of unique winding equipment of microscopic accuracy plus newly developed manufacturing techniques for precision, miniaturized parts. Dependability is guaranteed with ACE quality control. A tabulation of check points showing voltage ratio versus rotation is supplied for each unit.



**ACEPOT WITHOUT PADDING RESISTORS achieves output function within 0.25% with *smooth* curve that follows application requirements exactly.**



**SAME FUNCTION WITH PADDING RESISTORS follows *stepped* curve which impairs accuracy and introduces "tap-offs" that decrease reliability.**

To meet the exact requirements for your particular applications, ACEPOTS can be custom designed and mass produced with short lead time. ACEPOTS in AIA sizes are immediately available in sine, cosine, square law and logarithmic functions that meet applicable sections of MIL specs. Call, write or teletype Mr. W. W. Lyon, ACE ELECTRONICS ASSOCIATES, INC., 99 Dover Street, Somerville, Mass., SOmerset 6-5130, TWX SMVL 181.

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# A-C ADJUSTABLE-SPEED DRIVES

**Supplied by Normal A-C System, New Drive Mounts A-C Wound-Rotor Motor and D-C Motor on Single Output Shaft**

Two years ago, W. R. Harding of Westinghouse and W. E. Happel of Landis Tool Company discussed requirements of packaged precision grinding wheel drives. They were specifically interested in a variable-speed drive that could be powered by standard 3-phase alternating current. They agreed the drive should conform generally to the following specifications: Supply constant power in the range 15 to 60 hp at a speed of 1200 to 1800 rpm; operate from a standard a-c power source; have speed control with 1½ to 1 or 2 to 1 speed range, magnetic controls, automatic overspeed safety, limited starting torque, absolute minimum tune-up adjustment, and require no auxiliary cooling.

Fulfilling these specifications, Westinghouse announced at the recent 22nd Annual Machine Tool Electrification Forum a new line of packaged adjustable-speed drives. Mr. Harding, speaking for Westinghouse, said that the package contains a unique combination of an a-c wound-rotor induction motor, a d-c motor, and two groups of semiconductor rectifiers.

One set of rectifiers converts the a-c slip power from the a-c wound-rotor motor to direct current and supplies it to the armature of the d-c motor, where it is converted to torque. Conventionally this slip power has not been available as mechanical output power.

The second set of semiconductor rectifiers converts the a-c line voltage to direct current to energize the shunt field of the d-c motor. Since the field circuit is separately excited, you can control speed by inserting a rheostat in this shunt field circuit. The system readily permits inclusion of electronic and magnetic amplifier equipment for field control.

The desired design speed ranges were attained by proper selection of the base speed of the d-c motor. The relationship between its rated voltage and the voltage available from the a-c motor then determined the design speed range of the package.

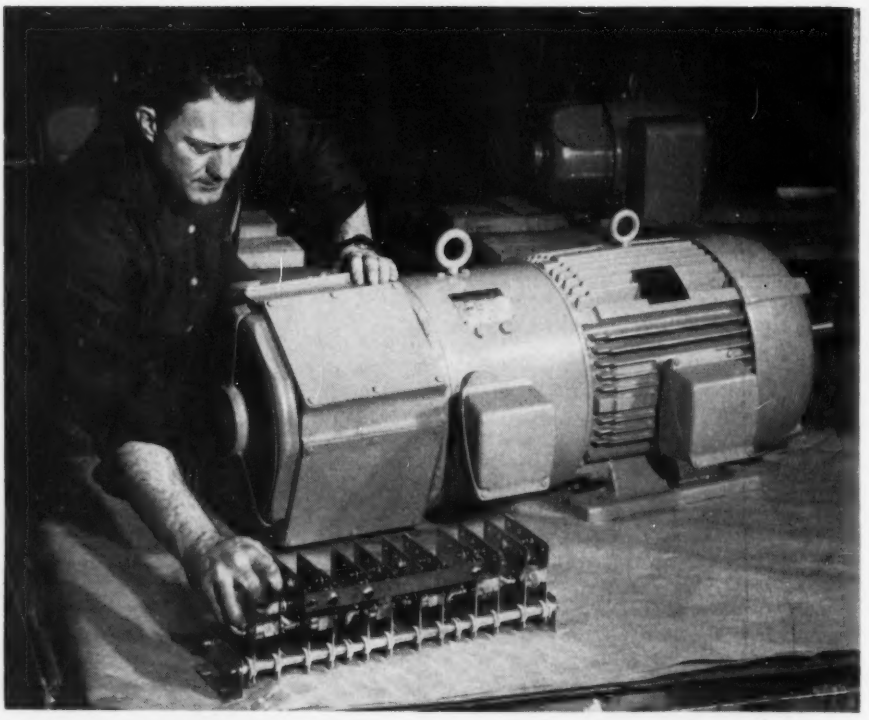

**FIG 1—15 hp Rectiflow drive with semiconductor rectifiers in foreground. In right side of housing: the a-c wound-rotor induction motor; in center: the d-c motor coupled on the same shaft; at left grouped behind covers for accessibility: slip rings, commutator, and brushes. The rectifiers can be located at any convenient site near the drive. Shown is the silicon rectifier bridge designed for use with the 15 hp unit.**

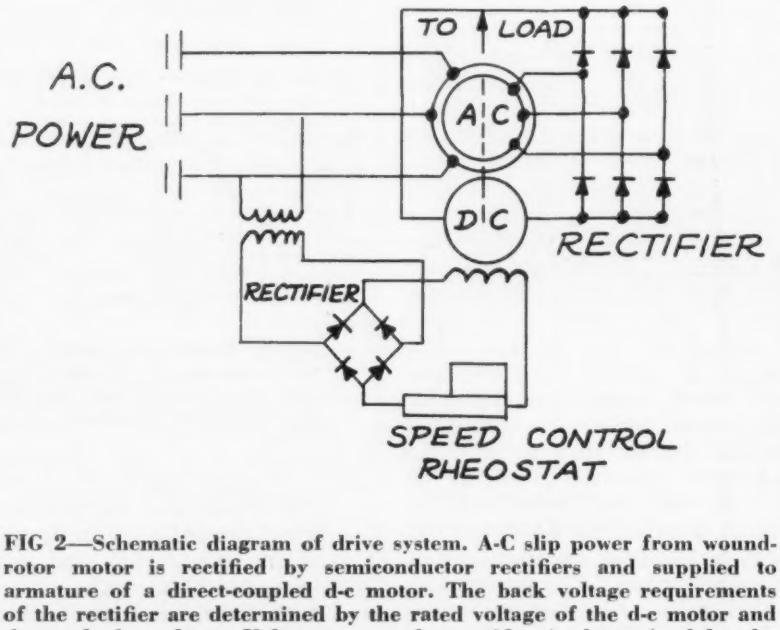


**FIG 2—Schematic diagram of drive system. A-C slip power from wound-rotor motor is rectified by semiconductor rectifiers and supplied to armature of a direct-coupled d-c motor. The back voltage requirements of the rectifier are determined by the rated voltage of the d-c motor and the peak d-c voltage. Voltage across the rectifier is determined by the secondary voltage of the wound rotor and the counter-emf of the d-c motor. Peak voltage is the d-c voltage that occurs when the drive is at full speed and the shunt field is applied at full strength. D-C peak voltage is twice the rated voltage on a rectiflow drive of 2 to 1 speed range and three times rated voltage for a drive with 3 to 1 speed range.**

### CONTROL DERIVED FROM D-C MOTOR

Tradenamed Rectiflow drives, the units derive their unusual characteristics from the d-c motor—the a-c motor operation is conventional. A counter-emf generated by the d-c motor bucks the rectified a-c rotor circuit voltage. The difference between the rectified rotor circuit voltage and this d-c counter-emf causes load current to circulate through the a-c rotor, the rectifier and the d-c armature. If the d-c motor field is weakened during operation, the counter-emf decreases, allowing more current to flow. This produces more torque in both a-c and d-c machines and the drive accelerates to a higher speed. As the speed increases, the rotor slip voltage decreases and the counter-emf increases. Accordingly, acceleration ceases when these voltages differ by the amount required to circulate running load current at the new speed.

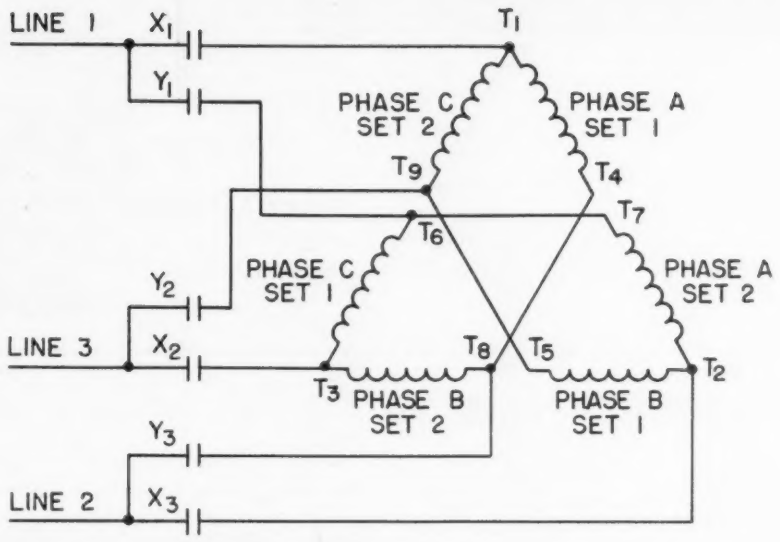


**FIG 4—Various methods of reduced voltage starting can be used to achieve reduced starting torque and starting current. Method shown here utilizes two standard line starters and double-delta primary on the wound-rotor motor. A-C starting current is reduced by 50 percent, starting torque by 25 percent.**

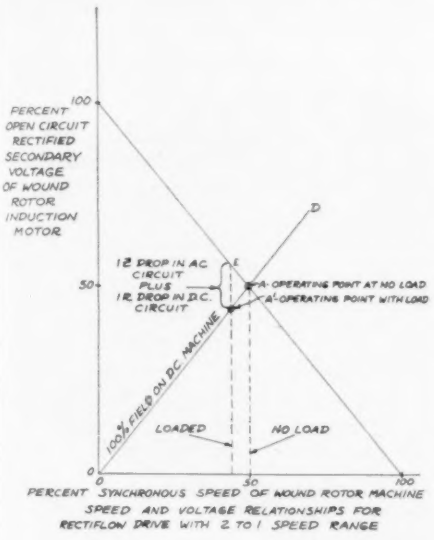
100
PERCENT OPEN CIRCUIT RECTIFIED SECONDARY VOLTAGE OF WOUND ROTOR INDUCTION MOTOR
50
0
D
I2 DROP IN A.C. CIRCUIT PLUS I1 R1 DROP IN D.C. CIRCUIT
E
A-OPERATING POINT AT NO LOAD
A1-OPERATING POINT WITH LOAD
100% FIELD ON D.C. MACHINE
LOADED
NO LOAD
0
50
100
PERCENT SYNCHRONOUS SPEED OF WOUND ROTOR MACHINE
SPEED AND VOLTAGE RELATIONSHIPS FOR RECTIFLOW DRIVE WITH 2 TO 1 SPEED RANGE

**FIG 3 — Rectified secondary voltage plotted against synchronous speed of wound-rotor for a 2 to 1 Rectiflow drive. Rectified a-c secondary voltage and d-c armature voltages are shown as functions of drive speed. Performance under these conditions is the same as for a wound-rotor induction motor with a small amount of external secondary resistance. When the d-c motor field is strengthened to 100%, the d-c voltage rises to the value marked D on the diagram. This voltage is higher than the secondary a-c voltage and no current will flow from the a-c wound-rotor through the rectifier and through the d-c machine. Drive speed will decrease until the point E is reached where the a-c secondary voltage is higher than the d-c counter-emf and current flows. This current produces torque in the a-c rotor and d-c armature. As additional load is applied, the speed drops slightly, the a-c voltage increases and the d-c counter-emf decreases to an extent permitting more current to flow until the required torque is obtained.**

### CONSTANT TORQUE CHARACTERISTICS

The combined characteristics of the wound-rotor motor and the shunt-wound d-c motor afford inherent constant horsepower characteristics. Proper use of certain d-c motor characteristics and selection of frame sizes make possible an economical and effective constant-torque drive. In drives designed for constant torque, the torques developed by the two motors are cumulative on the common shaft. If load is increased at any preset speed within the unit's designed range, the wound-rotor motor tends to slip, increasing the current in the d-c armature, and increasing the d-c torque. This characteristic gives stability under load.

At the synchronous speed of the wound-rotor motor, no voltage or current is available from the slip rings. This feature and the fact that the motors are assembled on a common shaft prevents the shunt-wound d-c motor from overspeed.

### PERFORMANCE

The unit operates over the desired speed range with a speed regulation of approximately 7½ percent, and an efficiency at full load over the entire speed range of 85 percent on 125 horsepower drives and down to 80 percent on the smaller drives. The power factor is approximately the same as for an a-c squirrel-cage motor, while the efficiency is approximately 5 percent lower. Many desired speed regulation curves from no load to full load are made

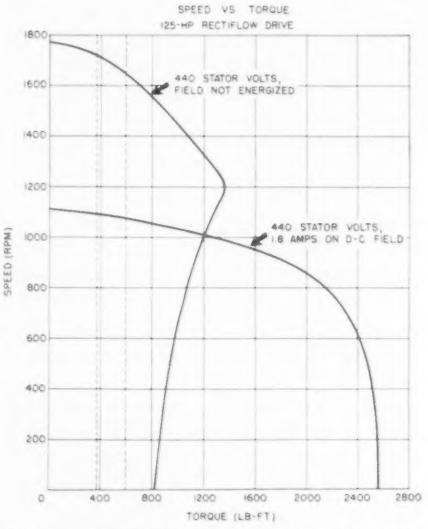


**FIG 5—Smooth starts can be obtained by exciting the d-c field at the same time the a-c contactor is closed. The time constant of the d-c field allows smooth torque build-up—notice difference between the two curves at start-up.**

available by the use of a series field on the motor.

An interesting aspect of construction is that the slip rings are mounted on the front end with the d-c commutator for accessibility and maintenance.

Variations to the basic circuit are possible. For example, regulators can be added in the d-c circuit to give variations in performance similar to those possible for typical d-c motors, but this changes the over-all performance of the drive. Also the basic drive circuit permits the addition of such devices as reactors, autotransformers and resistors for useful modifications.

Circle No. 135 on Inquiry Card

STAFF COLUMNIST

**Sidney A. Davis**

*Consulting Electromechanical Engineer*

# DAMPING FACTORS

## Dangers in Single-Source "Special" Components

High performance in a smaller package is basically incompatible with improved reliability in the face of increasingly severe environments. The design engineer is constantly balancing the one against the other, and methods for effecting the optimum compromise have been the subject of much study and a great many technical papers. The methods generally preferred are to select the best components, operate them well within ratings, and combine them in a package that can withstand the specified environments. There is, however, one aspect of the component selection process which, though not often considered, is all too frequently the starting point for a perpetual sequence of the most frustrating, time consuming and costly-to-solve problems. Be careful in selecting a complex, highly-engineered, single-source "special" component.

All too often, the project engineer, anxious to do an exceptional job, finds that Manufacturer A's precision transducer, specified as having "accuracies to 0.01%" over temperature ranges extending "as high as 200°C," will save him two servos and make his system a lot simpler. Maybe he's in a hurry, and using the transducer can cut out a lot of time as well. In brief, a new transducer, three times better than any previously made, permits him to approach his design problem from a fresh point of view, and come up with something better, smaller and (hopefully) cheaper. So he makes some kind of investigation, and designs it in.

At this point his career may take either of two general directions: his system may be a glorious success with personal praise from the government, and he becomes a promising candidate for chief engineer; or, he may get into trouble, depending on how well he has investigated the precision transducer before designing it in. He may find that

- Manufacturer A never made any before but merely had a new idea and was anxious to get funds to make a prototype.
- At temperatures "as high as 200°C" life is only one hour. Our design engineer requires 1000 hours. (Occasionally a components manufacturer is taken in by a parts manufacturer in much the same way.)
- The accuracy of 0.01% has a different meaning from the one he expected—*they* meant at room temperature, *he* meant over the temperature range.
- The transducer is a highly trimmed device requiring an engineer to carry out the costly and lengthy adjustments. When an engineer is available, samples can be made in 120 days at $1000 each.
- No transducer has been around long enough to indicate whether the highly trimmed in accuracy will stay after aging has set in on the parts and materials.
- Because of its unusual operating principles the transducer develops unique behaviorisms which the designer had never even specified, since they just didn't arise in conventional devices for similar functions. (If a designer really wants to pin down *everything* by specification, experience reveals that a costly and massive document requiring the combined efforts of project and standards engineers as well as component manufacturers is necessary.)
- Similarly, a set of unique problems appear in using the transducer. Its light weight frame is not sufficiently rigid to permit mounting without introducing a couple of tenths of distortion and throwing the accuracy way out.
- The company that developed the transducer is an offshoot of a larger parent company, formed by some bright engineers to exploit a new idea. They are new in business, have unreliable vendors, no credit and weak finances. The transducer company with its limited capital, can't be sufficiently sure of staying in business to warrant a gamble on its products. With limited capital, just how would they go about backing up a production order, if it ever went that far?
- The company doesn't even have a team capable of putting the item into production, given the necessary capital.

A list of this type could be continued endlessly, depending upon the specific situation. The point to be concluded is this: while the research scientist or even the R & D man can permit a certain amount of free rein to his imagination, the project engineer must be a more stubborn and even skeptical person. He should be more concerned with delivering a good piece of gear, on time, and with a fair profit to his company, than he is with the unusual, the tricky, and the clever solution. This doesn't mean he ignores the possibility of real originality. Such a course would be a severe limitation to his competitive position. But it does mean that *anything new* becomes the focal point of his anxieties, whether it be in new components, circuitry, etc. And no matter how well the underlying theory of the novel device, he is never quite convinced that it will do the job until he sees it working well, and over an extended period, it has passed environmental tests, and he knows he can get as many more as he wants at reasonable price and delivery.

These words of warning do not intend to deny the fact that small companies formed by bright young engineers are a vital part of our engineering achievements. A great many, if not most, of our newest products are developed in outfits such as this, and the "odd-ball" ideas they develop have contributed immeasurably to our wonderfully compact and accurate control equipment. I'm merely saying it's just good business sense to check carefully before getting involved with a new small outfit.

WORTH FILING

**Zinc—Mine to Market Outline**

96-page book contains a variety of fundamental data on zinc's history, sources, production, significant properties, and important applications. Illustrated with photographs, charts, graphs and drawings, the book describes comprehensively the full scope of the Zinc industry, and includes latest research and production findings and unfamiliar aspects of the versatile metal.

Source: American Zinc Institute
New York 17, N. Y.
For your copy: Circle No. 148 on Inquiry Card

WORTH FILING

**Magnets, Magnetizers, Demagnetizers**

12-page catalog lists and describes stock permanent magnets, magnetizers and demagnetizers.

Source: Indiana Steel Products Company
Valparaiso, Indiana
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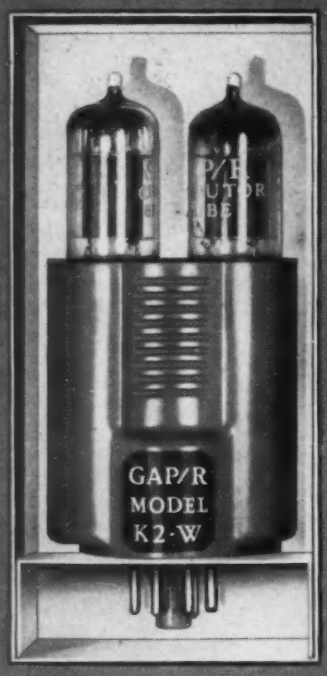
# PLUG FOR ANALOG




**FAST DC AMPLIFIER:** Model K2W is an efficient and foolproof high-gain operational unit for all feedback computations, fast and slow. A number of special varieties are also in quantity production. **($24.00)**

**SLOW DC AMPLIFIER:** Model K2-P offers long-term sub-millivolt stability, either by itself or in tandem with the K2-W. High-impedance chopper-modulated input. Filtered output to drive balancing grid or follower. **($60.00)**

**SERRASSOID GENERATOR:** Model K2-G produces a fixed triangular wave of 100 V peak-peak, at 500 kcps. Use it for a quadratic rounding in diode networks, and for many other non-linear recreations. **($29.00)**

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## COMPONENTS

### Indox V Ceramic Magnets

A highly oriented ceramic permanent magnet material, Indox V, makes possible savings in both material and space because of its reduced size and non-critical components. Made of barium-iron oxide oriented in the direction of pressing, Indox V produces an exceptionally high peak energy produce of $3.5 \times 10^6$ as compared to $1.0 \times 10^6$ for the non-oriented type ceramic permanent magnets. The material's light weight (0.181 lb/cubic inch) makes its energy product comparable to Alnico V on an equivalent weight basis. The length of Indox V is only 28 percent that of Alnico V at optimum operation, and the area is only 57 percent of conventional non-oriented ceramic magnets. Properties include a coercive force ($H_c$) of 2,000 Oersteds and a residual induction ($B_r$) of 3840 Gauss. At the point of peak energy product, $B_d$ is 1920 Gauss and $H_d$ is 1820 Oersteds. Indox V has a wider high-efficiency operating range than Alnico V because of its broader maximum energy product. Other properties of Indox V are high resistivity, in the 10,000 to 20,000 ohm-cm range, and a low incremental permeability. Indox V is well suited for applications such as medium size d-c motors, synchronous drives, traveling wave tubes, high fidelity loudspeakers, separators, magnetic chucks, and a variety of tractive devices where size is important. The Indiana Steel Products Company, Valparaiso, Indiana.

Circle No. 182 on Inquiry Card

### Subminiature Mica Capacitors

Subminiature molded mica capacitor designed for guided missile applications is said to be 73 percent smaller and 69 percent lighter than next-smallest molded mica unit. The new component, known as "Missil-Mite", weighs one-half gram and is only 0.370 in. long, 0.190 in. wide and 0.110 in. thick. It meets most applicable MIL-C-5A requirements; has a capacitance range of 5 mmf through 240 mmf (with tolerances from ±2 percent to ±20 percent); is available in C or D characteristics in capacitance ranges below 50 mmf and in C, D or E characteristics in capacitance range from 51 mmf through 240 mmf; and has a working voltage of 300 volts at 85°C. Its dielectric strength is 200 percent of rated voltage. Micamold Electronics Man. Div. General Instrument Corp.

Circle No. 212 on Inquiry Card

WORTH FILING

### Barden's Ball Bearing Book

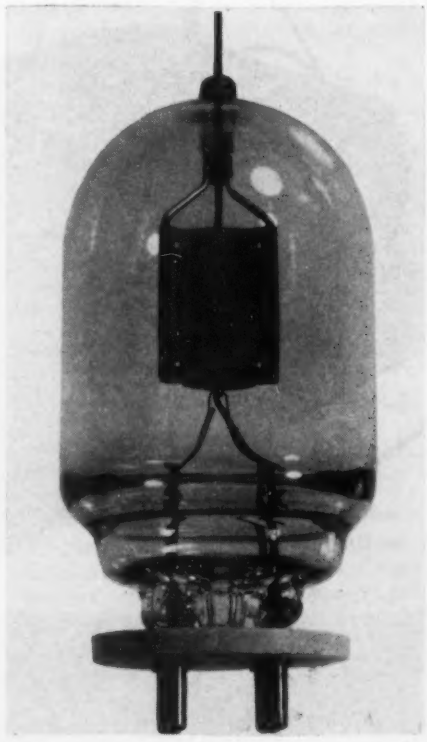
12-page booklet, "Ball Bearing Yield and System Isoelasticity", written to assist users in the application of precision instrument bearings, offers comprehensive background data on radial and axial play, axial take-up and preloading, isoelastic bearings and achievement of system isoelasticity. Of interest to gyro builders is a section on requirements for spin axis bearings subjected to transient or vibratory forces.

Source: The Barden Corporation
Danbury, Conn.
For your copy: Circle No. 153 on Inquiry Card

### Antenna and Microwave Components

Open-leaf, short form catalog lists over 850 standard items in microwave and antenna fields in complete and comprehensive groupings.

Source: Diamond Antenna & Microwave Corp.
Wakefield, Massachusetts
For your copy: Circle No. 130 on Inquiry Card



### Ruggedized High Vacuum Rectifier

New ruggedized version of the 705A, half-wave, high vacuum rectifier has radiating fins and improved mechanical design that allows its use in systems where a reliable tube and the ability to withstand adverse conditions of shock and vibration are required. Major applications for the new rectifier include airborne radar, electrostatic precipitators and high voltage power supplies. Vacuum Tube Products Co. Inc. Oceanside California.

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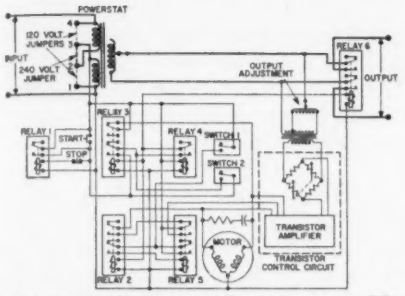
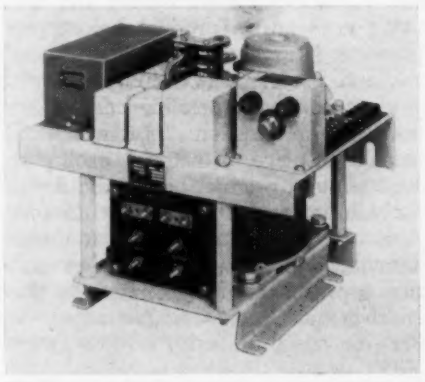



**Schematic diagram of automatic filament voltage regulator.**

### Automatic Filament Voltage Regulator

Automatic voltage regulator provides gradual run-up power to minimize surge strain on filaments of complex vacuum tubes in sensitive laboratory, industrial and communications equipment. A special transistorized control circuit, a plug-in unit, actuates at the proper time to maintain the pre-set output voltage level. Maximum voltage run-up time is 45 seconds with other speeds available; exact time is proportional to the output voltage setting. The transformer element is a special double wound assembly with primary and secondary wound on a single core but electrically isolated; primary consists of two windings which may be parallel or in series connected for 120 or 240 volt duty, 50/60 cycle, single phase lines. Input voltage range is 108-132 volts on 120 volt service and 216-256 volts on 240 volt service. Sensitivity is within a 1.0 volt band for any output setting from 9 to 24 volts. Superior Electric Co., Bristol, Conn.

**Circle No. 143 on Inquiry Card**



WORTH FILING

### Silectron Steel

16-page data sheet on Silectron grain-oriented cold-rolled 3 percent silicon steel contains detailed data as to typical curves, grading, annealing cycle and other information used primarily in motors and lamination for power transformers.

**Source: Allegheny Ludlum Steel Corp. Pittsburgh 22, Penn.**

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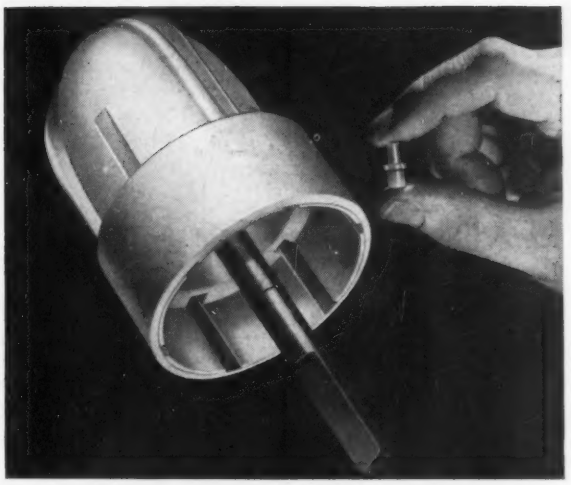

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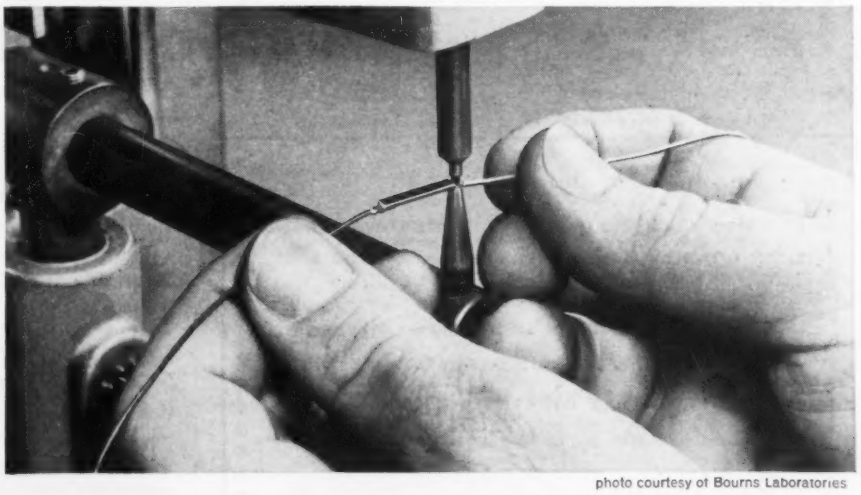

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Heat must be kept at a minimum in joining leads to the resistance element tabs of this sensitive TRIMPOT® potentiometer. The long pulses of most welders would transmit heat to the .001" Evanohm resistance wire, altering its characteristics and impairing performance. Low-temperature soldering might mean "cold" joints. With a Weldmatic, Bourns makes welds in 1½ milliseconds—no chance for heat transfer beyond the weld! Result: high component accuracy, low reject rate. Write for Weldmatic literature.

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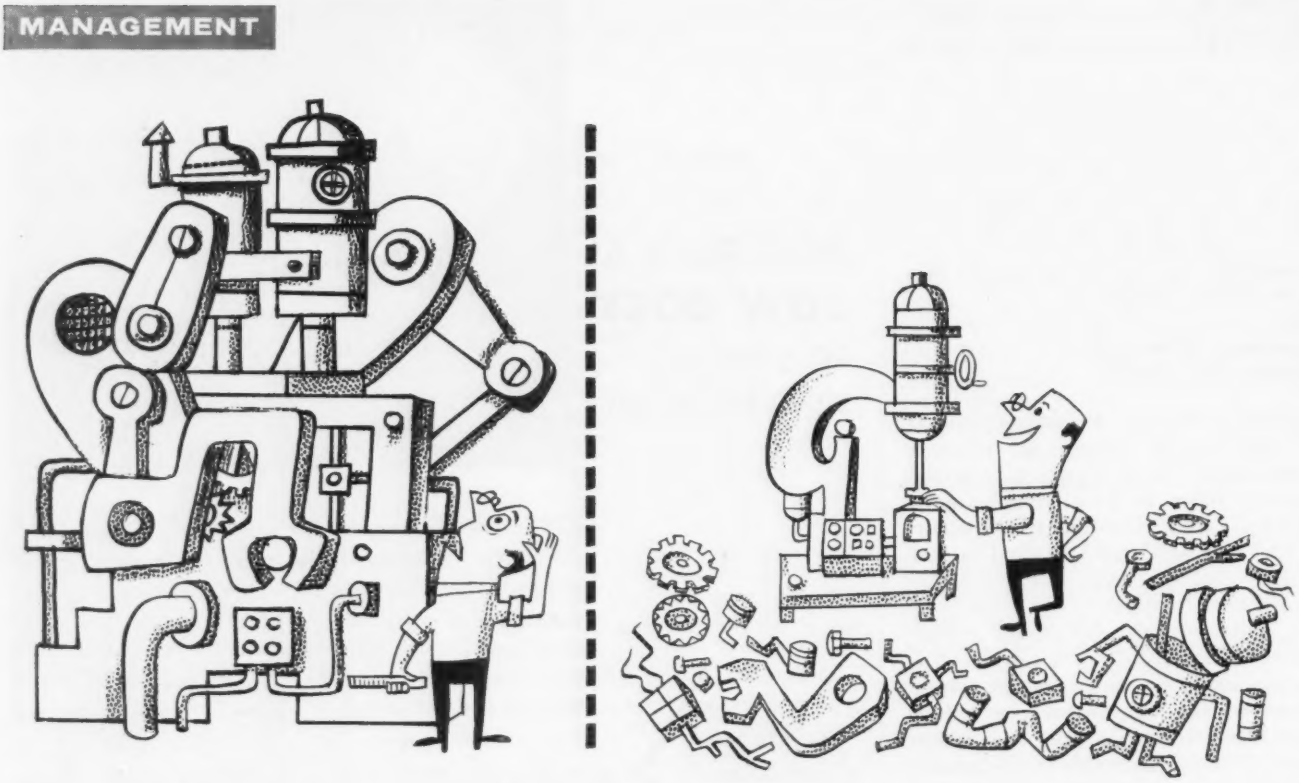


# VALUE ENGINEERING:

## Design For Profit

In value engineering every material, every part, every operation in a design must pass these tests.

**Can we do without it?**

**Does it do more than is required?**

**Does it cost more than it's worth?**

**Is there something better to do the job?**

**Can it be made by a less costly method?**

**Can a standard item be used?**

**Considering the quantities used, could a less costly tooling method be used?**

**Does it cost more than the total of reasonable labor, overhead, material and profit?**

**Can someone else provide it at less cost without affecting its dependability?**

**If it were your money, would you refuse to use it?**

If the answers to any of these questions is yes, then you are not getting good value.

What is value engineering? In simple terms it is a technique for providing accurate yardsticks for measuring the true value of everything that goes into a product before production investment is made. It involves objective appraisal of equipment, systems and programs to achieve essential requirements of a product at lowest possible cost. It appraises a design in terms of the question: "Is it worth it?" It measures the value of each piece of material, each part, each component that goes into a product before the design is finalized. It is not only an important tool of cost information for engineers, it is also a way of looking at design problems to obtain new ideas for doing a job at less cost. The value engineering approach is characterized by five questions applied to each item of cost.

- What is it?
- What does it cost?
- What does it do?
- What else will do the job?
- What will that cost?

As an example of how these questions may be applied to a specific item, consider an ordinary cap for a fire hose. It consists of two pieces, each of which is secured to opposite ends of the hose. What is it? A brass casting, threaded, and slotted for hand gripping. What does it do? It keeps dirt out of the hose. What does it cost? A little more than $2.00 for each cap. What else will do the job? From a specialty supplier we obtain neoprene caps. What do they cost? $0.50 each. These caps will do the job of keeping dirt out of the hose. Now, apply a little creative thinking. What do we usually do to keep dirt out of our

lawn sprinkling hose? You guessed it. We couple the two ends together. Now we have accomplished the required function at no cost.

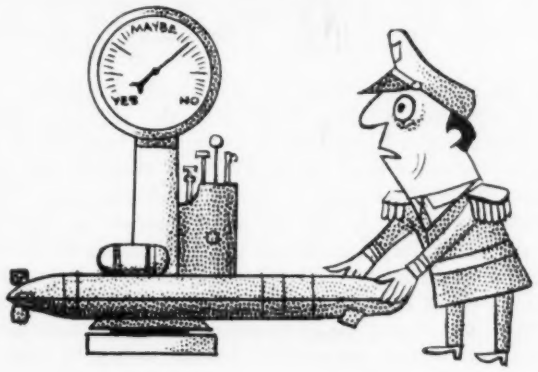
Answers to these basic questions are obtained by use of value engineering techniques, systematically performed in a value engineering job plan.

These techniques will be taught in a series of one-day seminars presented by the Industrial Education Institute of Boston, Mass., in cooperation with industrial organizations and government activities in major cities throughout the country. Special emphasis will be given to dramatic savings from these techniques achieved by BuShips of the U.S. Navy, General Electric, Philco, Raytheon, Westinghouse, Stromberg-Carlson and Ford Motor Co. Instructors will include Albert Sikorsky, Value Engineer, BuShips, USN; Jack Scheinman, Advisor to Small Business Administration; and Bernard Eades, Chief Value Engineer, Stromberg-Carlson.

Background of the development of value engineering, some of its techniques, and examples of its application were described to us by Mr. Sikorsky.

## BACKGROUND

The concept of value engineering, Mr. Sikorsky said, arose out of a search by the Navy Bureau of Ships for a way to combat rising costs that were pricing them out of a proper defense build up. Surveying industrial approaches to cost reduction, the Bureau found the value analysis program at the General Electric Co. to be adaptable to their needs. They applied the GE analytical approach to obtain value appraisals of equipment during its design and development.




The early application of value engineering within the Bureau, its Naval Shipyards and then with private shipbuilding contractors encouraged them to apply it in their procurement contracts for electronic equipment. The voluntary establishment of value engineering departments by many of the Navy's contractors was evidence to the Bureau that value engineering is a profitable management-engineering tool for private industry as well as the military.

## TECHNIQUES

Value engineering uses at least seventeen well-defined techniques. Mr. Sikorsky described four of the most important for us.

- *Get the Facts and Know the Cost.* Question requirements, specifications and design details that appear to be unnecessarily restrictive or are not essential. Establish the cost of each component, including the price of procurement, maintenance and operation. If properly done, this technique brings into sharp focus the high cost areas to be given attention later on.

As an example, consider the facts of cost in the practice of treating electronic equipment with fungicide spray. This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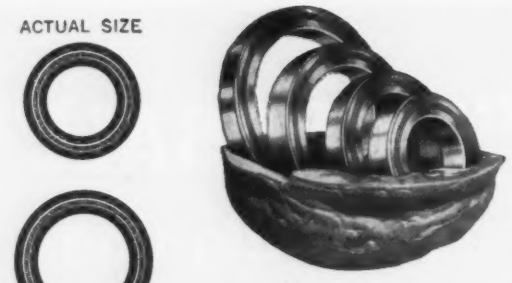
ACTUAL SIZE



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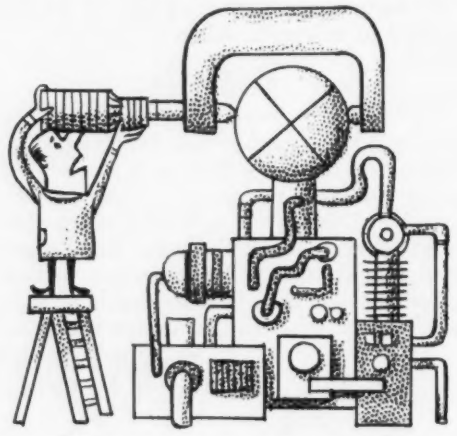
practice came about during World War II when many of the Bureau's electronic equipment components were made of organic materials, and as such, were fine nutrients for fungus. Under certain conditions of temperature and humidity found in many combat areas, fungus would attack these materials and destroy their usefulness. The spray treatment was an effective way of fighting this destruction. After the war, the electronics industry developed inorganic materials now universally used in electronic components. These new materials don't support the growth of fungus under any conditions. Yet, until quite recently the Bureau was still using the spray treatment. Those who opposed its continued use ran into the argument that the spray treatment afforded some measure of insurance, "just in case someone laced a cable with cotton cloth" and furthermore, "it obviously doesn't cost much." Just how much was the Bureau paying for this insurance. The average annual expenditure was found to be $350,000. Obviously this was too much to pay for a function that was rarely performed.



• *Evaluate the Function.* Try to describe function using just a verb and a noun. Determine the primary function and then list the secondary function. For instance, a small transformer cover used in a very large quantity was found to cost $0.42. The primary function of the cover was to *provide shielding.* A film of paint applied to the cover served a secondary function to resist corrosion of the metal cover. When costs were detailed, it was found that it cost $0.17 to make the metal cover that provided the primary function, but it cost $0.25 to paint the cover to satisfy the secondary function. It seemed logical to try to make the secondary function less expensive. In answer to the question what else will do the job, it was found that corrosion protection could be achieved by chemical treatment of the cover at only $0.03, a 53 percent reduction in total cost.

• *Evaluate by Comparison.* Compare the function and cost of one item with the function and price of something comparable. You do this every day. You compare the cost of clothing, transportation and so forth. Once you have decided on what you need, you choose a way or a thing that satisfies your need at the lowest cost. Mr. Sikorsky illustrated this technique applied by the Bureau in a study of a military receiver. By comparison, this receiver was priced at twice the cost of another that was considered by many to be equally as good. It contained many expensive features including a complex system of projecting a frequency dial reading on a frosted glass. This system consisted of a projection lamp, plus a spare in case the one in use burned out, a lense and a mirror that reflected the dial image on the frosted glass attached to the front panel. Even the function of using the spare projection lamp was intricate. When the lamp in use burned out, you merely twisted a little lever and the spare would move into position to do its job. No doubt someone had considered the important factor of maintenance when he designed this intri-

cate little feature, but he forgot that people didn't bother to replace a lamp until both had burned out. The little unit cost well over $200.00, and added to the overall complexity. By comparison, a single straight-forward frequency dial would have cost one tenth the price and would have performed the same job. The elimination of the extra parts would have added to the receivers reliability.

• *Creative Thinking.* This technique is an obvious requirement in the solution of any type of problem. Obvious or not it belongs on a check list of value engineering techniques as a reminder of its importance. An example of how value engineering highlights creative thinking is illustrated by the Navy's new method of securing electrical cable aboard its ships. The old method, standard practice for many years, was to form individual black iron straps to fit the shapes of various cable runs. A master electrician conceived the idea of applying the technique of metal strapping so commonly used in commercial packaging. The idea lay dormant until value engineers determined the cost savings. Now the method is universally used in the Navy. In the conversion of one large aircraft carrier this new method saved well over $100,000.

## JOB PLAN

In applying his techniques, the value engineer uses a step by step approach, called the job plan, as guide lines in planning and carrying out a project with efficient use of time and effort. With these phases to guide him he will avoid the trap of holding out for a perfect solution.

*Information Phase.* Define well the various functions and costs and determine the high cost areas that need attention.

*Speculative Phase.* Attack the high cost areas and propose alternative ways of doing the job.

*Planning Phase.* Select the best of the alternative solutions for final processing.

*Execution Phase.* Prove the value of the selected alternatives, i.e., show that they do the required job at less cost.

*Reporting Phase.* Properly document the technical and cost data to support acceptance of the alternative ways chosen.

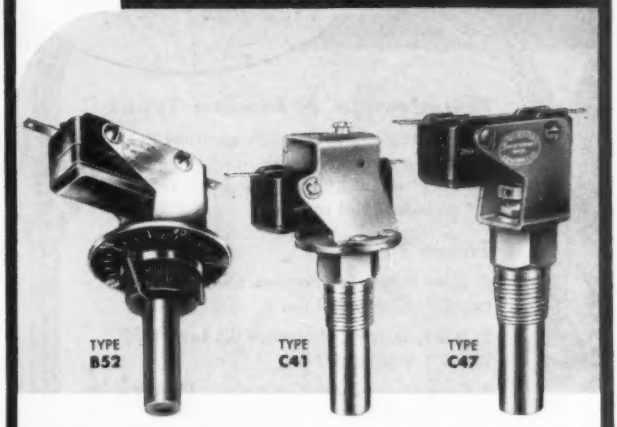
## CAUSES OF HIGH COSTS

Before the Bureau applied value engineering to its procurement contracts for electronic equipment it conducted a study to find out why its equipment was costly and overcomplex. For the answers they went directly to their contractors who gave them three very good reasons.

The first reason given for high cost was the Bureau's specifications. The military applies general specifications for shock, vibration, and premium materials across the board to safeguard their equipment from every conceivable mishap. When applied to certain equipment, these specifications contribute nothing except cost, complexity, size and weight. Quite often the environmental conditions from which the equipment is protected by these specifications simply does not exist at points of installation.

The second reason given for high costs is lack of time


SPACE OR WEIGHT LIMITATIONS? B52 | C41 | C47

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| Temperature Ranges | Type C41 & C47 100° or 200° between 0° and 425° F limits. Type B52 calibrated 40° F spans between 30° and 120° F. |
| Thermal Assemblies | various immersion lengths . . . liquid-filled seamless brass bellows operate by hydraulic action |
| Switch Ratings | 15 amps or 20 amps at 115 or 230 volts A.C.; also D.C. switches available upon specification |
| Switch Actions | N.O., N.C., or Double Throw, no neutral position |
| Electrical Connection | attached directly to screw or solder terminals on switch |
| Size & Weight | approx. weight . . . 4½ oz., approx. size . . . 3⅞" x 2" x 1¼" |
| Variations | design variations available upon specification |

**UNITED ELECTRIC** *manufactures a complete line of temperature, pressure and vacuum controls. For applications requiring custom-built units or modified standard units, call upon a UE application engineer for recommendations. Write for complete specification and pricing data on the Type B52, Type C41 or Type C47 local mounted temperature control, and for information regarding other United Electric temperature controls.*

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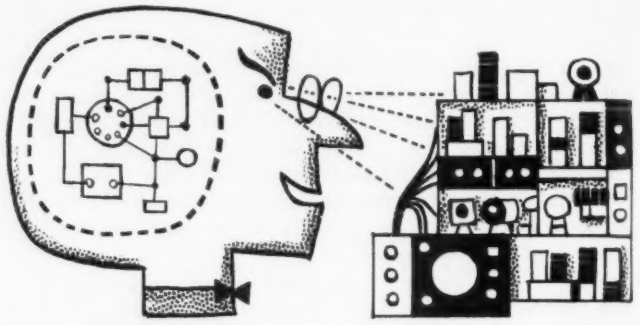
in development contracts. Every early design such as a developmental model, contains a certain number of design features that can be simplified, eliminated or redesigned for reasonable cost if time is allowed for a fresh second look. Too often the cost and complexity for meeting a requirement is not justified by the marginal technical advantage it provides.

Using an acceptable developmental model as a guide for production specification is general practice. The specification writer hesitates to deviate from the developmental model, afraid the equipment coming off the production



line will not meet the original performance requirements. For this reason, Mr. Sikorsky said, every effort must be made to remove the high cost and over complexities in the design before production specification is written.

The third and probably biggest reason given for high cost is lack of incentive. Contractors who have proposed a relaxation of military specifications have sometimes been penalized by having the resulting savings subtracted from the contract price. In some cases, the contractor's profit, which is based on a percentage of total contract cost, is also lost to him. Contractors are well aware of this possible penalty and consequently shy clear of any suggestion that might save the government money.

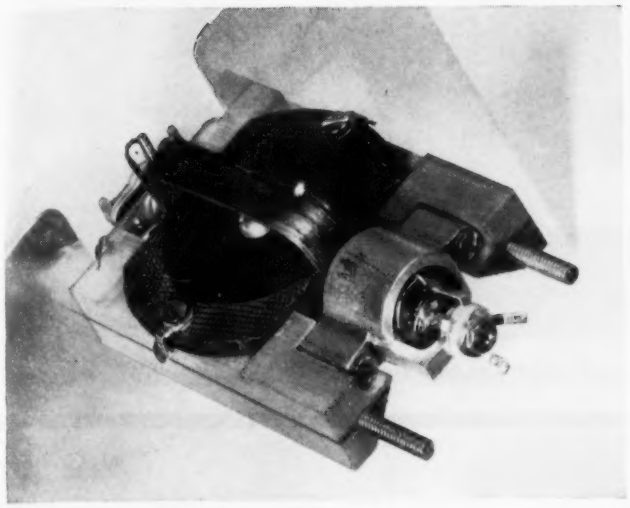
### PROCUREMENT CONTRACTS INCLUDE VALUE ENGINEERING

With these three reasons for high cost in mind the Bureau set out to apply value engineering in its procurement contracts. They established a specification for value engineering of naval electronic equipment, which required the contractor to conduct value engineering study of all the elements of design, construction, procurement, installation and maintenance of an equipment, including the specifications, to achieve only necessary functions, maintainability and reliability at minimum costs.

The contractor is required to perform the value engineering study before going into production. Even before he produces any parts, sets up his tooling or assembly lines, he has to submit value engineer proposals to the Bureau for evaluation. The approved proposals are then applied in the form of specification changes. The cost of the value engineering study is borne by the Bureau as part of the overall contract cost. An incentive to do a good job is offered the contractor in the form of a share of the resulting savings. The share will vary from 10 to 40 percent of the savings depending on the quantities of equipment procured and the total dollar cost of the contract.

Value engineering proposals submitted to the Bureau involve only changes in specifications or contractual requirements. All savings made to improve efficiency within the specifications are retained by the contractor.

The second value engineering seminar will be held in Chicago, June 25th at the Sheraton-Blackstone Hotel. For more information on future value engineering seminars, write to Mr. Jerome Glass, Industrial Education Institute, 25 Huntington Ave., Boston 16, Mass.



**Locking Contact Wattmeter**

Variations in electrical power factor that are not monitered may significantly complicate control of wattage. It is now possible to directly monitor and control electrical power with a locking contact wattmeter. High and/or low limits of wattage may be preset by pointers that may be turned anywhere on a dial. Control action, which may be in a number of forms, is initiated when a limit is reached. A core magnet movement of the type used in VHS meter-relays is combined with the movement of a standard dynamometer type wattmeter to form the new instrument. The VHS-type movement is on the same plane as the voltage coil of the wattmeter, and moves with the voltage coil as is turns with the field of the stationary current coil. When the measured power reaches the preset limit, a contact on the indicating pointer touches a contact on a fixed pointer closing a circuit to an external slave relay that triggers control action. Current through the contacts also flows through the coil of the core magnet movement, and develops sufficient torque to lock the contacts firmly together.

Capacity of the field coil ranges from one to 20 amps ac. The instruments are calibrated so that with a given amperage limit, watts may be read and controlled on the dial when nominal voltage is 110, 220, or 440 ac. Standard rating of the core magnet coil and contacts is 25 milliamperes dc, 75 to 125 volts, although higher ratings are obtainable. Assembly Products Inc. Chesterland, Ohio.

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WORTH FILING

**Steelback Electrical Contacts**

4-page folder describes projection-welded steelback electrical contacts and discusses forms, materials, applications, advantages, properties, methods of attachment, and projection-welded assembly service. Listed are over 100 available sizes of projection-welded contacts, showing different head diameters and thicknesses, contact material thickness, radius of face if domed, and the diameter and height of projection.

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**Continuous Loss-In-Weight Feeding Systems**

8-page, three-color bulletin describes simplex and duplex gravimetric feeders for liquids or solids and provides explanatory text, dimensional drawings and tables, photographs, schematic drawings and performance charts.

Source: B-I-F Industries
Providence 1, R. I.
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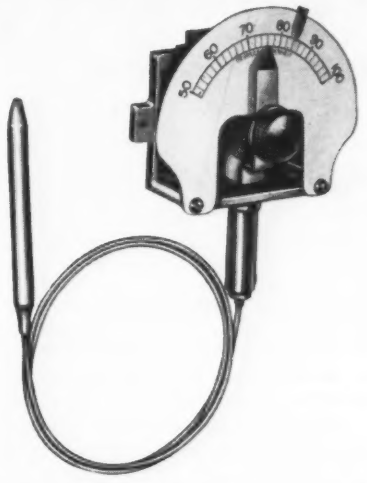
Range Limits —100 to +600°F **E65N**



**New Design gives maximum accuracy at low cost!**

The UE Type E65N control is offered in basic skeleton form so that it may be easily incorporated, or designed into equipment, without the need and expense of an enclosure. Enclosures, however, are available upon specification. Setting and indication are clearly visible on a single scale allowing easy reference between the setting and controlling temperatures. Ideal for incubators, centrifuges, oxygen tents, sterilizers, and other applications where it is necessary to control and indicate temperature of gases, liquids and hot plates.

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| Temperature Ranges | A wide variety of scales between −100 & +600°F. |
| Thermal Assemblies | Standard 4′ capillary with several bulb styles and sizes. |
| Operation | Liquid filled bellows assembly expands or contracts with heating or cooling thus actuating a snap-acting electrical switch at desired control point. |
| Switch Ratings | 15 amps 115/230 volts AC. DC and other special switches available. |
| Switch Actions | Normally closed; normally open; and double throw, no neutral position. |
| Electrical Connections | Lead wires attached to terminal on switch. |
| Size & Weight | 1 lb; scale plate 4½″ wide. |
| Variations | Design variations available on request. |

**UNITED ELECTRIC** *manufactures a complete line of temperature, pressure and vacuum controls. For application requiring custom-built units or modified standard units, call upon a UE application engineer for recommendations. Request Type E65N Design Catalog Sheet for complete specification and pricing data and for information regarding other United Electric temperature controls.*

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*Case 1.* **Three Springs for an Automatic Washing Machine.**

## CASE HISTORIES IN SPRING DESIGN

### The Case for Consultation

Most of you have certainly had a course or possibly two involving spring design from an elementary point of view. Unfortunately, you find out just how elementary when you experience a spring failure in one of your designs or when you send for a spring design manual of the type published by spring manufacturers or technical publications. (See ELECTROMECHANICAL DESIGN, September - October 1957, November-December 1957 isues.)

Today there is an easy way out. Once you set the design specs, it pays to check with a spring specialist at a spring manufacturer. Most spring companies are happy to provide spring consultants at no cost in the interest of avoiding failure or improper applications of their product.

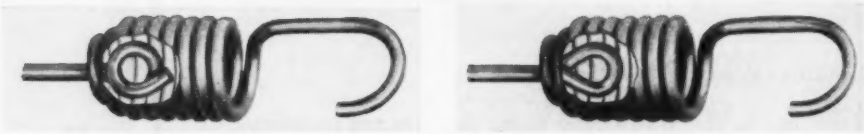
Here are some case histories from the files of the Associated Spring Company, Bristol, Connecticut.

Case 1. Automatic Washing Machine. Two major considerations in spring design for washing machines are vibration-control and motor-speed regulation. To function properly the spinner must agitate both verically and laterally. The product designer decided that a flat spring could damp the horizontal vibration best and set specifications for its shape and size. Vertical vibration presented a problem involving space and the proper method of attaching the springs to the frame.

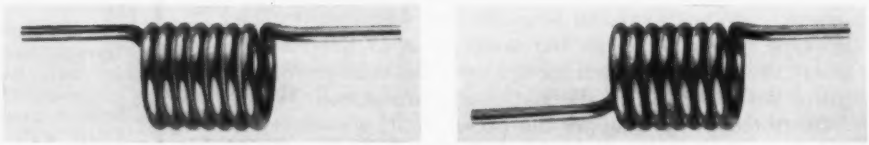
Also, to protect the drive motor from overload at varying speeds the designer conceived a safety clutch spring that presented a trickly problem of providing great strength with sufficient torsional action to compensate for the uneven rate of operation. In these spring problems the designer laid down the specs and then called in one of Associated Spring's consultants.

The consultant checked the flat spring designed to control the horizontal vibration and came up with the recommendation for a specific spring steel that has the desired long-lasting resiliency, with the suggestion it be cadmium-plated for corrosion resistance. To handle the vertical damping action, he designed a barrel-shaped spring with offset ends which eliminate the problem of end-fracture due to excessive stress-concentration, resulting in maximum performance within the limited range of loading and motion involved in the washer installation.

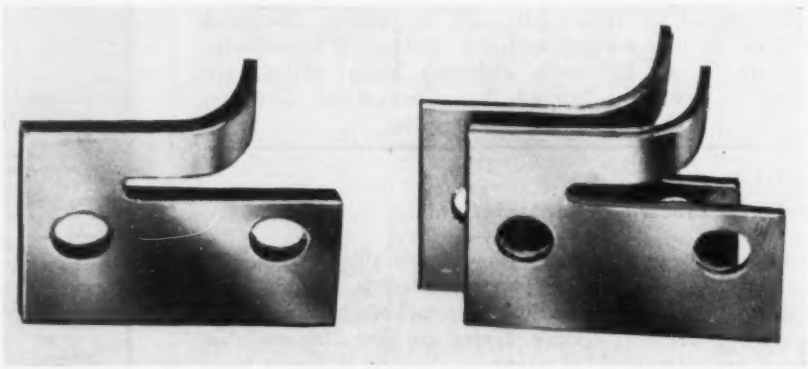
For the clutch the consultant called in his consultant in Associated Spring; the team developed a special design, wound from a strip of tapered material, which absorbs the torsional load in graduated amounts, thus preventing motor overload.



*Case 2.* **Brake Return Spring. In the old design *(left)* a connecting link inserted in one end of the spring had a sharp end that rubbed on the coils in the tapered end of the spring, causing wear and excessive breakage. At Associated Spring's suggestion the loop in the connecting link was redesigned *(right)* with an additional half turn, ending breakage.**



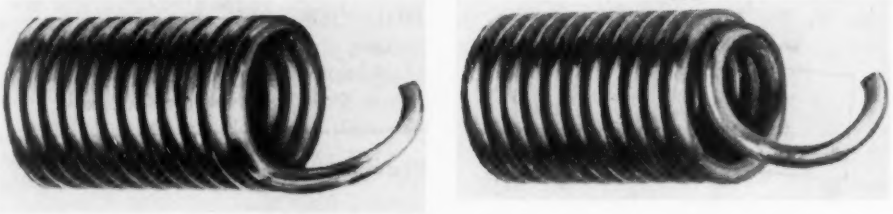
*Case 3.* **Air-Valve Torsion Spring. Original design *(left)* presented a serious breakage problem. After consultation the spring was redesigned *(right)* to use a slightly larger wire, with a larger radius for offset bend, and more generous-sized hole in the valve-body for the insertion of the ends. Fatigue tests proved the new design satisfactory.**



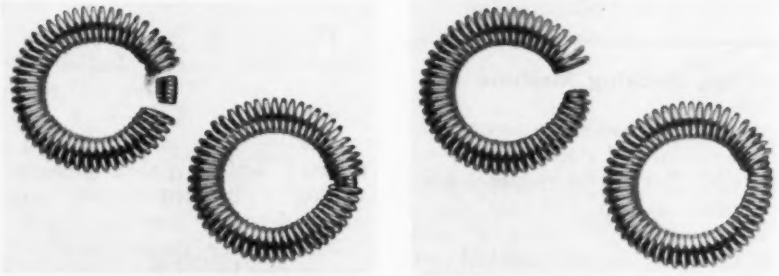
*Case 4.* **Stop Spring. Original spring *(left)*, formed of 3/64 inch material, frequently broke. Problem was solved by a pair of springs *(right)*, each made of thinner stock, to obtain the same unit load and deflection with reduced stresses.**

Circle No. 137 on Inquiry Card

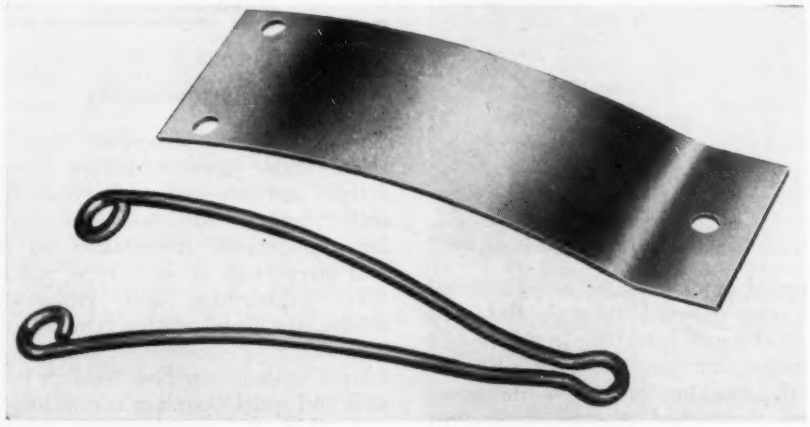
*Case 5.* **Lever for a Jet Engine. Original design *(left)* would have entailed costly machining or forging. Spring engineer recommended a new design *(right)* using a standard ball-joint bearing press-fitted into one end, and a spacer on the other. New design can be stamped, eliminating machining and brazing.**



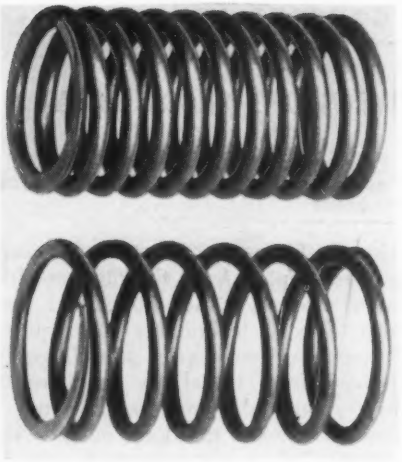
*Case 6.* **Door-Return Spring for a Range. First design *(left)* did not have sufficient fatigue-resistance, due to stress concentration in the hook-ends. Redesign *(right)* reduced the size of the end coils, thereby lowering the stress in this area of the spring and eliminating the hook breakage.**



*Case 7.* **Retaining Spring for a Circuit-Breaker. In the original design *(left)* an extension spring was formed into a complete-circle "garter" spring by inserting a smaller coil spring into the two ends as a kind of screw-plug. Assembly cost was high and the operation was difficult. Associated Spring's redesign eliminated the small plug-spring *(right)*, joined the two ends by reducing the diameter of one end slightly so that it could be inserted into the other end. Assembly was considerably speeded up and the joint was actually stronger than before.**



*Case 8.* **Snubber Spring for Automatic Washer. The flat spring *(top)* originally used for this purpose did not provide the versatility in assembly that was offered by the wire-form which replaced it *(bottom)* and saved material and manufacturing costs.**



*Case 9.* **Refrigerator Spring. Original design *(top)* with 11 coils of 0.120 inch diameter wire, proved to be understressed. The redesign *(bottom)* called for the use of 0.105 inch wire and only 7 coils; provided ample stress-carrying capacity; delivered substantial savings in material and manufacturing costs.**

### Protect Components in Vacuum Storage Carts

To prevent contamination, minimize the formation of surface oxides and protect against physical damage while awaiting final assembly, components can now be stored in a vacuum storage cart. The cart, a mobile unit with its own self-contained vacuum pumping system, has six storage compartments. Within the cart a common manifold, 1-1/4 inches in I. D., extends the full length of the axis; an evacuation line leads from the center of the manifold to the mechanical vacuum pump, a 13-cfm gas-ballasted two-stage unit, driven by a 3/4 hp electric motor. The pumping system evacuates any of the six compartments to a pressure of 50 microns within one minute.

Individual manifolds connect the compartments to the evacuation system. So that each compartment can be separated from the evacuation system individually, the line connecting each compartment to the main manifold has a manually operated 1-inch high vacuum valve, controlled by a handwheel on a shaft extending through the side panel of the cart. To permit the inflow of outside air to each compartment when breaking vacuum, the wall of each compartment has 1/2-inch solenoid-operated vacuum valves. Toggle switches on the sides of the cart operate these valves and a manually operated needle valve on the front of the cart adjusts the rate of inflow. The main manifold has an electrical vacuum gage, with indicator dial mounted on the front of the cart and a sensing range from 0 to 1000 microns.

Circle No. 142 on Inquiry Card

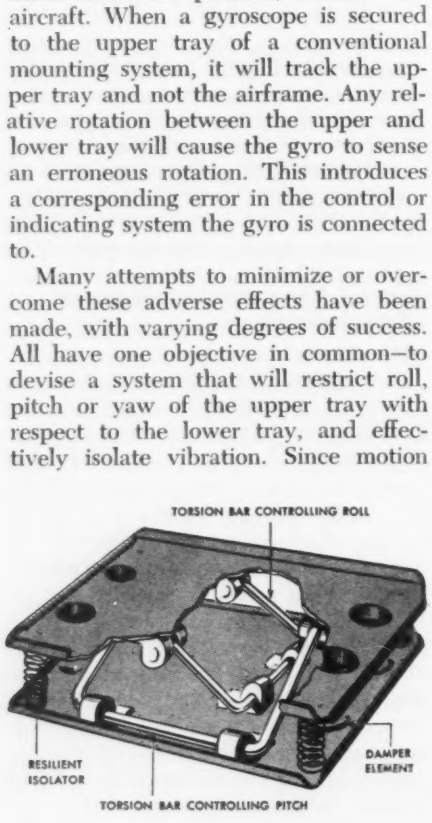
**COMPONENTS**

# GYROSCOPE SHOCK MOUNT

### Torsion Bars Solve Gyro Mount Problem

Aircraft Gyroscopic Instruments cannot be isolated from the airframe like other air-borne instruments and controls. Special techniques are required because a gyroscope's usefullness is derived from its ability to sense its own rotational displacement from a fixed reference position, outside the aircraft. When a gyroscope is secured to the upper tray of a conventional mounting system, it will track the upper tray and not the airframe. Any relative rotation between the upper and lower tray will cause the gyro to sense an erroneous rotation. This introduces a corresponding error in the control or indicating system the gyro is connected to.

Many attempts to minimize or overcome these adverse effects have been made, with varying degrees of success. All have one objective in common—to devise a system that will restrict roll, pitch or yaw of the upper tray with respect to the lower tray, and effectively isolate vibration. Since motion

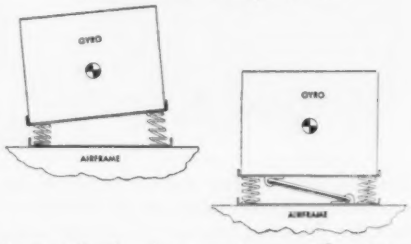



restriction and vibration isolation are fundamentally incompatible conditions, the design of an effective mounting system involves complex theoretical and practical problems.

One approach to the problem was to install the gyro in a center of gravity mounting system. This method decouples the various modes of vibration and provides optimum vibration isolation, however, it does not provide any positive force to maintain parallelism.

Using the positive action of rigid torsion bars, General Shock Mount Corp. and Lear Inc. have developed jointly the Federal Gyro Mount. Each mount has two rigid torsion bars that hold the top tray parallel with the bottom tray. One controls relative movement between trays caused by pitch, the other controls relative movement caused by roll. When the aircraft is in smooth level flight, the upper tray is parallel to the lower, and the torsion bars are not in use. Their presence in no way affects the efficiency of the vibration control system. When the aircraft is in a climb or turn. the weight of the gyro shifts, changing the loading and deflections of the springs causing an ordinary mounting system to go out of parallel. The Federal mount remains virtually parallel because the rigid torsion bars exert positive forces which offset the weight shift. Federal Shock Mount Corp., New York 56, N. Y.

Circle No. 163 on Inquiry Card

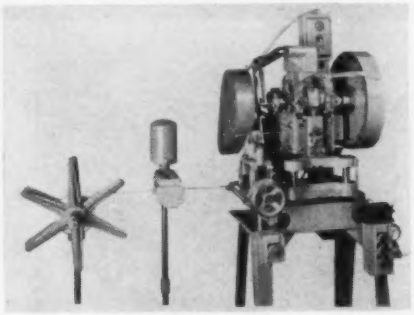



Left—Climb, dive, or turn without torsion bars causes error resulting from rotation of top tray. Right—with torsion bars, trays remain virtually parallel.

### Metal Tag Marking Machine

New press produces wrap-around tags from aluminum coil stock or other soft metals and alloys. The machine marks and punches a hole, and cuts tags of any length up to 7″ using ¾″ wide coil stock. Tags are also marked with identification data set with interchangeable type in a multi-line holder mounted in the punch holder of a die set. A tang is blanked on one end of the tag and an elongated hole or slot is punched at the opposite end.

Used for identifying pneumatic, hydraulic or electrical lines, the tags are



wrapped around tubing or piping with the tang inserted through the elongated slot and bent over in the reverse direction. An operator need only actuate the machine, and when the preset count is reached, the machine automatically shuts off. Noble and Westbrook Manufacturing Co., East Hartford, Conn.

Circle No. 150 on Inquiry Card

### X-Band Microwave Wattmeter

X-band microwave wattmeter, a standard since calibration depends only on measurements of length, mass and time, replaces the water calorimeter. The instrument is relatively independent of the voltage standing wave ratio, and the electrical calibration is simplified and accurate. The design minimizes the effects of mismatch produced by small alignment; allows rapid production checks on magnetrons, klystrons; and has an in line wattmeter for radar. Power range measurements are 10 to 200 watts, with accuracy of 2 percent. Wayne Kerr Instruments, Philadelphia, Penna.

Circle No. 154 on Inquiry Card

### Proximity Limit Switch

Operating life of new proximity limit switches is independent of the number of switching operations performed because they are built without moving parts or contacts. Electrical output of the device—24 volts d-c at 0.335 amperes—is adequate to drive static control elements and 24-volt d-c relays and solenoids.

The versatile device consists of an encapsulated sensing element that contains an open "C" core and two windings which are elements of a variable reluctance bride circuit; and a steel-encased sealed control element containing a balance circuit, amplifier, phase detector, precision flip-flop circuit, transistor output amplifier, and power supply.

In addition to the modest maintenance demands and good reliability characteristics inherent in static equipment, proximity limit switches afford: precision and repeatability, rapid response, high repetitive speed, and protection from shock, vibration, corrosion and humidity. Westinghouse Electric Corporation, Pittsburgh, Pa.

Circle No. 160 on Inquiry Card

WORTH FILING

### Miniature Thermocouples

28-page catalog describes and illustrates four basic miniature thermocouple designs—gasket, bayonet, protected, and shielded—each for particular applications. Information on uses and advantages of each type, installation, calibrations and temperature ranges, details of construction, adapters and mounting accessories, and thermocouple leads is supplied. Various terminals and quick-coupling connectors are also illustrated and temperature conversion tables are provided.

Source: Thermo Electric Co. Inc.
Saddle Brook, N. J.

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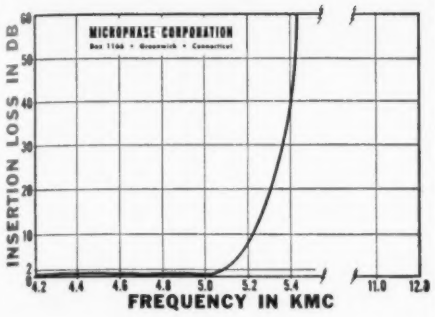


### RF Waveguide Filters

Unique resonant sections and conventional waveguide techniques have been employed in the construction of a new line of RF waveguide filters that provide very sharp cutoffs and low insertion loss in the passbands. The unit illustrated is a low-pass type cutting off at 5 kmc/s, carefully matched to achieve a maximum loss of only 0.75 db in the passband, with a minimum attenuation of 60 db from 1.08 $f_c$ out to 12 mcs/s.

Designed to handle up to 100 watts, the filter is fitted with a UG-149/U flange at one end and a UG-148B/U at the other and withstands severe environmental conditions. Similar performance can be achieved with units in the S through X bands. Microphase Corp., Greenwich, Connecticut.

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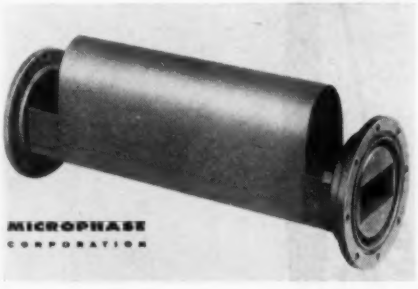


WORTH FILING

### Infrared Optical Elements

An 8-page brochure gives the physical properties and detailed specifications of Servofax arsenic trisulfide glass, a stable, non-toxic, non-corrosive homogeneous glass that transmits infrared. Today's infrared instruments rely on precise optical systems; Servofax is particularly well suited for their exacting requirements. Over 50 different optical flats, approximately 25 single element lenses and a number of achromat lenses are listed as standard. For unique systems, this glass may be "ground" to specifications in the form of prisms, windows, plates, lenses, and one piece domes up to 18 inches in diameter.

Source: Servo Corporation of America
New Hyde Park, New York

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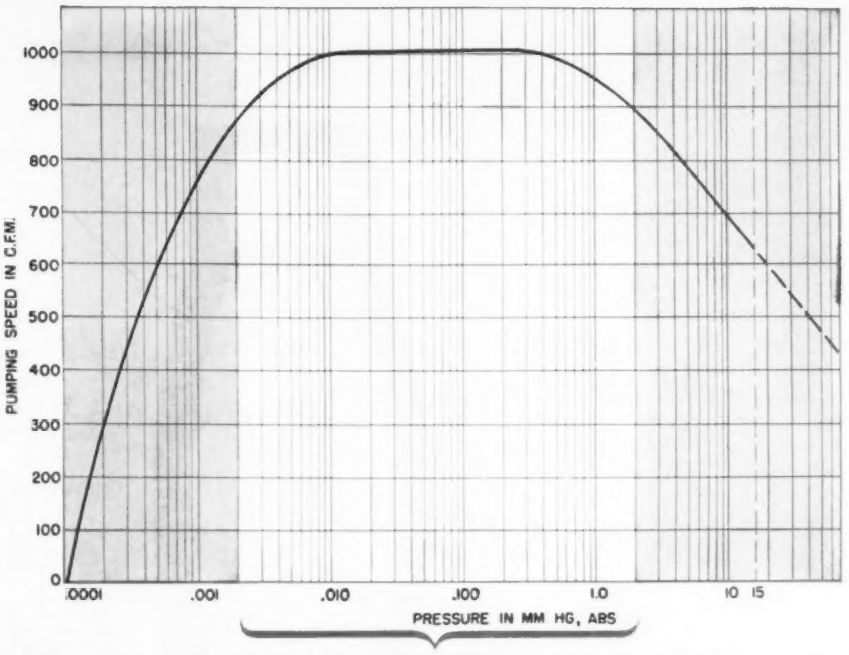


## Do You Use Vacuum In This Range?

From millimeters to microns . . . in this region the significant economy of the KINNEY KMB Mechanical Booster Pump is self-evident, as shown by the performance curve above. And, this high efficiency is doubly attractive because these KINNEY Pumps provide *clean, dry* Vacuum . . . no backstreaming . . . automatic operation . . . no stalling problems from gas bursts.

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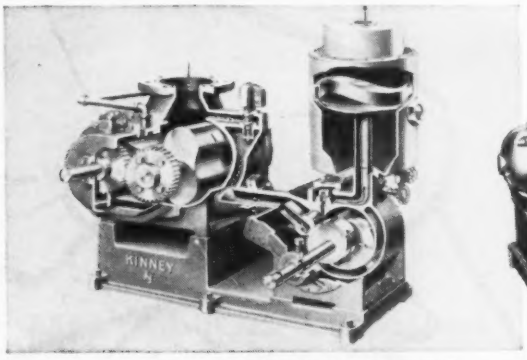
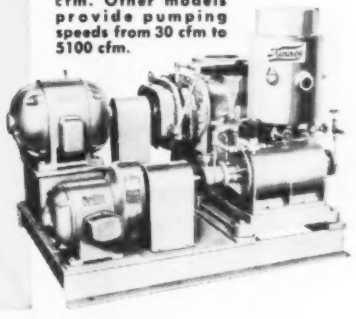
## MECHANICAL BOOSTER HIGH VACUUM PUMPS

The KINNEY KMB Pumps have proven themselves in the most difficult applications. Their performance, even where outgassing of materials renders other pumps inoperative, stamps them as the major contribution of the decade in High Vacuum service. Models range from 30 to 5100 cfm free air displacement.





KMB 1200 with free air displacement of 1230 cfm. Other models provide pumping speeds from 30 cfm to 5100 cfm.

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## COMPONENTS

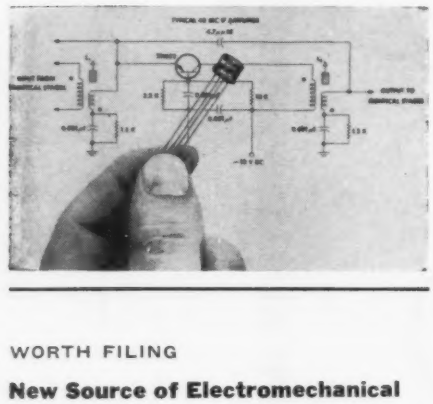
### High Frequency Diffused Base Germanium Transistor

A new high frequency diffused base germanium transistor enables manufacturers to attain high gain at high frequencies, making it especially useful for television IF's, radio RF's and very high frequency oscillators. The same transistor, available in a JETEC TO-05 outline package has a typical switching time of 25 millimicro-seconds in a non-saturated circuit configuration making it well suited for use in ultra high speed computer applications.

Having a 200 megacycle typical maximum frequency of oscillation and a 90 megacycle typical alpha cutoff frequency, this PNP transistor delivers 50 db gain at one megacycle and 13 db gain at 50 megacycles. In the 43 megacycle IF amplifier circuit shown the 2N623 diffused base transistor provides 15 db typical device gain and 20 milliwatts available unit output at this frequency.

Other significant electrical characteristics: —30 volt breakdown voltage and 40 milliwatts total dissipation at 25°C. The unit is heat cycled from —55°C and room hlumidity to +75°C and 95 percent relative humidity for four complete cycles over an eight hour period. Texas Instruments, Inc.

Circle No. 213 on Inquiry Card



WORTH FILING

### New Source of Electromechanical Components

Koontz-Wagner Electric Company, Inc., a South Bend, Indiana, electrical firm, has entered the commercial market as a developer and producer of electromechanical components.

The new venture, featuring a catalog of 13 specialized valves, solenoids and switches, is an outgrowth of 20 years of association with automotive, aircraft and ordnance manufacturers. Each of the cataloged components has been tested and proven in aviation and vehicular applications for which it was developed.

The company contemplates no production of items for "off-the-shelf" standardization, but rather plans volume production of specifically tailored adaptations of catalog items along with development of components to meet specific problems.

Cataloged items suitable for adaptation to a wide variety of applications include solenoids which operate within temperature ranges from minus 100°F to 700°F; one, two and three-way solenoid operated valves for fuel, oil or air; speed sensitive switches with automatic "on" or "off" features and a selection of components marked by compactness, low current drain and reliability under difficult environmental conditions.

Source: Koontz-Wagner Electric Co., Inc.
South Bend, Indiana
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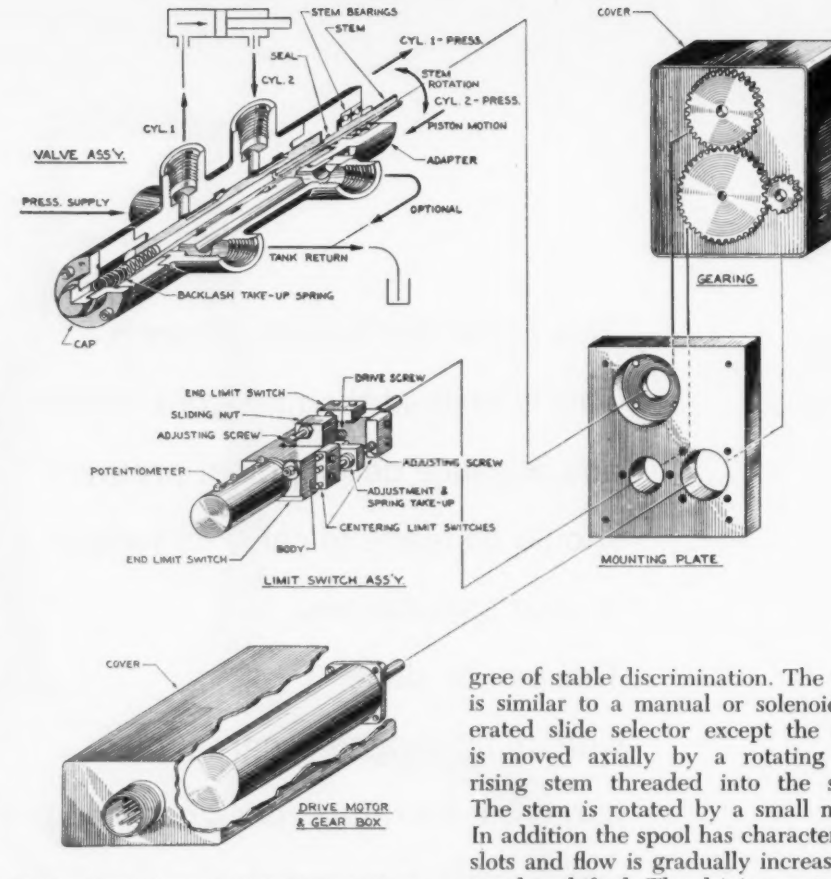


### Motorized 4-port Selector Valve

Suitable for highly refined servo control or simplest switch operation, motorized hydraulic selector valve provides direction selection and flow control without shock and with high degree of stable discrimination. The valve is similar to a manual or solenoid operated slide selector except the spool is moved axially by a rotating non-rising stem threaded into the spool. The stem is rotated by a small motor. In addition the spool has characterizing slots and flow is gradually increased as spool is shifted. The driving motor can be selected to provide rapid or slow spool movement compatible with the cylinder or hydraulic motor controlled. United Hydraulics, Inc., Dayton 7, Ohio.

Circle No. 161 on Inquiry Card

WORTH FILING

### Potentiometers with Humor

Engineers who want to string along with a gag can get new product information on liquid filled-potentiometers, size 8 servomotors, all-metal precision potentiometers, differentials . . . in a light, humorous manner . . . for free.

Source: Helipot Corporation
Newport Beach, California
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on Inquiry Card

WORTH FILING

### Subminiature Switch

4-page bulletin describes Unimax line of snap-acting subminiature switches and a wide variety of actuators, giving photographs, detailed drawings, descriptions, operating characteristics, and electrical ratings.

Source: Unimax Switch Division
Wallingford, Conn.
For your copy: Circle No. 66 on Inquiry Card

### High-speed Polarized Relays

New series of high-speed polarized relays are engineered to provide fast action with freedom from bounce. Under some conditions, the SPDT relays will handle over 1,000 pulses per second with high sensitivity and excellent stability. Two independent coils, coil resistances are available up to 5,000 ohms each coil, control contacts rated variously in the range 60 mils to 2 amps. Operated from voltages to 120 a-c or d-c, the relays are designed for a wide variety of applications. Hart Manufacturing Co., Hartford 1, Conn.

Circle No. 156 on Inquiry Card

MATERIALS

# PLASTICS FOR ELECTROMECHANICS

### Flame Retardant Electrical Insulation Laminate

Flame retardant electrical insulation laminate meets NEMA GPO-1 physical and electrical standards for fiber glass reinforced polyester laminates and can operate continuously at full Class B temperatures. Recognized by Underwriters' Laboratory "for sole support of current carrying members to temperatures of 150° C", the material can be used in UL approved motors and appliances and as barriers and insulating supports in switchgear and power distribution apparatus. This economical product is available in thicknesses from 1/16 inch through ⅝ inch; in 36 x 72 inch sheets that can be cut to 36 x 36 inch and 24 by 36 inch size. Glastic Corp., Cleveland, Ohio.

Circle No. 155 on Inquiry Card

### Laminated Plastic Simplifies Induction Heater Terminal Unit

Replaceable coil terminal for induction heaters uses laminated plastic material for insulating parts. This material meets the specifications for good dielectric strength, mechanical strength, low moisture absorption at high frequencies, dimensional stability and good machinability.

The coil terminal remains fixed on the heater at all times. Standard work coils can be interchanged quickly and easily. All fixtures, guides and jigs can be mounted directly on the terminal, assuring accurate alignment during the heating cycle. After heating is completed the entire coil and fixture assembly is removed from the terminal and held for subsequent production runs. Flexibility of design permits either top or bottom use of all coil assemblies, in either right- or left-hand positions.

Circle No. 141 on Inquiry Card

WORTH FILING

### Fusion Bond Finishes

4-page folder describes Corvel cellulosic, nylon, polyethylene, K-51 (chlorinated polyether) and other new fusion-bond finishes for use in cladding metal parts. Finishes are dry powders specially processed for use in a fluidized cladding process now available under license.

Source: National Polymer Products
Reading, Penn.

For your copy: Circle No. 79 on Inquiry Card

### Flame-Resistant Laminate

Flame-resistant laminated plastic with high insulation resistance and low moisture absorption is available both as a standard laminated plastic and as copper clad material for printed circuit bases. This new material is recommended for critical electrical and electronic applications where fire danger must be considered. Laminate is ideal for use in color television sets where high voltages may cause fires, in computers and telephone equipment where manufacturers are concerned about the loss by fire of expensive apparatus, and in aircraft electrical systems. Constructed of a paper base bonded with a modified phenolic resin, new Grade XXXP-467 is a hot punching material that meets all NEMA requirements for XXXP stock. National Vulcanized Fibre Co., Wilmington 99, Del.

Circle No. 164 on Inquiry Card

WORTH FILING

### Polytetrafluoroethylene Base Resin

4-page bulletin describes Fluorosint TFE resin, a polytetrafluoroethylene base composition designed to improve the mechanical and thermal properties of the pure compound without materially affecting its unique electrical and chemical characteristics. Charts and tables compare its properties to Teflon.

Source: The Polymer Corp.
Reading, Penn.

For your copy: Circle No. 64 on Inquiry Card

WORTH FILING

### Copper-clad Phenolite

6-page folder titled "A Better Foundation for Printed Circuitry", charts performance and illustrates eleven grades of copper-clad materials for printed circuit applications. Typical test values for each of the Phenolite copper-clad grades are presented in tabular form, and information on the manufacture and fabrication of copper-clad Phenolite and printed circuit assembly methods is given.

Source: National Vulcanized Fibre Co.
Wilmington 99, Del.

For your copy: Circle No. 147 on Inquiry Card

WORTH FILING

### Copper-clad Plastic Laminates

4-page illustrated bulletin includes tables listing physical characteristics of copper-clad plastic laminates for electronic printed circuits.

Source: Taylor Fibre Co.
Norristown, Pa.

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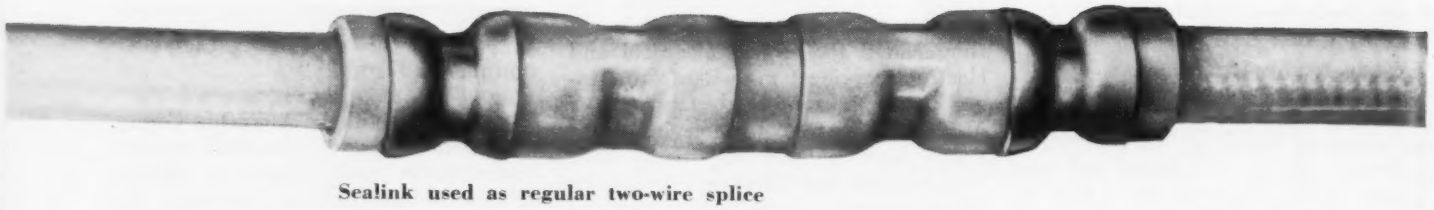
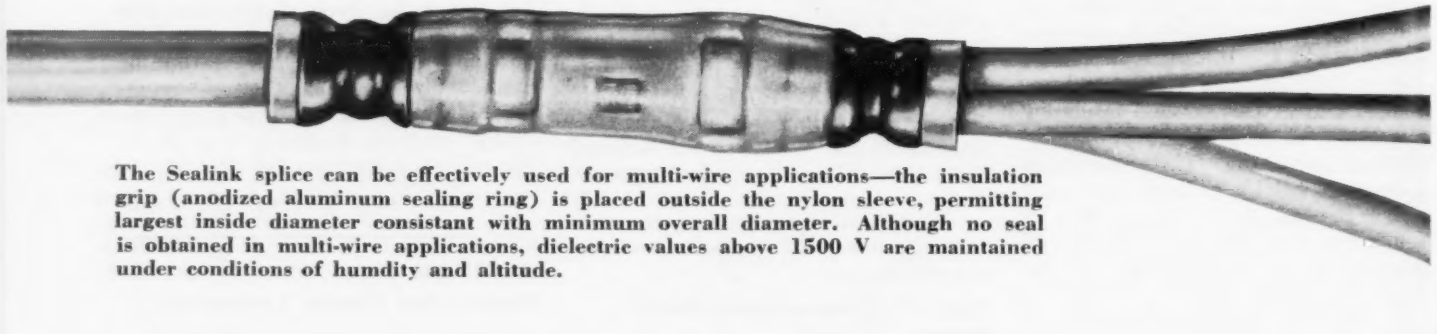
DESIGN TIME SAVER



Sealink used as regular two-wire splice



**The Sealink splice can be effectively used for multi-wire applications—the insulation grip (anodized aluminum sealing ring) is placed outside the nylon sleeve, permitting largest inside diameter consistant with minimum overall diameter. Although no seal is obtained in multi-wire applications, dielectric values above 1500 V are maintained under conditions of humdity and altitude.**

# Evaluating Insulated Splices

**B. B. Baschkin, Project Engineer**
**Omaton Division, Burndy Corporation**

A cable splice is a common component frequently used in the fabrication, modification, and repair of wiring harnesses. The unique feature of any splice is in its application since its sole function is to replace an equivalent length of cable. Thus in any splice evaluation performance is best rated on how well the splice functions mechanically and electrically, and how it compares dimensionally to the equivalent length of cable it replaces.

The electrical and mechanical performance factors involved in cable splice evaluation are all interrelated. For example, an attempt to increase the conductivity of the link can be readily achieved but usually at the expense of a bulkier and consequently heavier connector. Any attempt to improve the mechanical and electrical characteristics of this connector is generally accompanied by compromising the physical characteristics—weight or bulk. Yet the reduction of the physical parameters, the limit being equal to the cable itself, is a primary consideration. Thus the "ultimate" design is one in which each splice characteristic has a quantitative measure equal to its counterpart on the cable. With this in mind let us proceed to these quantitative measurements.

## DIMENSIONAL PERFORMANCE CHARACTERISTICS

$$\text{Weight Ratio} = \frac{\text{weight per unit length of cable}}{\text{weight per unit length of splice}} \qquad (A)$$

While theoretically possible, it is highly doubtful that any splice design utilizing copper for the connecting link, and a dielectric equivalent to the cable dielectric, can result in a weight ratio factor of unity, without seriously effecting the conductivity performance or the mechanical properties of the splice. The degree to which the limit of unity is approached is a valid index by which the design and performance can be measured.

$$\text{Bulk Ratio} = \frac{\text{diameter over cable insulation}}{\text{maximum diameter over splice}} \qquad (B)$$

This limit once again cannot be achieved. The splice dielectric should overhang the cable dielectric with sufficient clearance to permit easy insertion of the cable insulation accounting for all variations of cable diameters.

## MECHANICAL PERFORMANCE CHARACTERISTICS

$$\text{Tensile Ratio} = \frac{\text{tension to break splice connection}}{\text{maximum breaking strength of cable}} \qquad (C)$$

Any cable splice can be so designed and made that its tensile strength is equal to or stronger than the tensile strength of the original cable. Thus in this instance, the ratio of unity can not only be achieved but exceeded. Full tension splices are manufactured for various utility overhead-line conductors. The practical limit, however, is the degree to which tension is a realistic requirement in the application as well as the effects on the weight and bulk ratios that a relatively high mechanical performance would impose. Military and aircraft specifications call for an equivalent tension ratio between 60% and 70% based on the cable ranges under consideration.

| Cable | A | B | C | D | E | Mean Performance Factor |
|---|---|---|---|---|---|---|
| AN10-12 | .85 | .63 | .83 | 1.00 | 1.00 | .86 |
| AN14-16 | .52 | .63 | .98 | 1.00 | 1.00 | .83 |
| AN18-22 | .69 | .68 | .99 | 1.00 | 1.00 | .87 |
| AN22-26 | .58 | .68 | 1.00 | 1.00 | 1.00 | .85 |

**Connectors subjected to this analysis were Burndy Sealink environmental insulated splices. Four sizes were designed to cover the following ranges of copper aircraft cables in the order given in the table reading from top to bottom: PS-10, PS-14, PSM-18, PS-22. Each connector was tested with the maximum cable accommodated in its application range. The mean performance factor is the arithmetic average of the five parameters. Without attempting to lend any extra value to one of these chosen standards, the mean performance of the combined ratings is a measure of the degree achieved in comparison to the "ultimate". The application engineer should normally concern himself not only with the composite rating but with the individual factors since he is in an excellent position to evaluate that particular factor in his application that he would prefer to weight rather heavily.**

ELECTRICAL PERFORMANCE CHARACTERISTICS

$$\text{Conductivity Ratio} = \frac{\text{conductivity of installed splice}}{\text{conductivity of equivalent cable}} \quad (D)$$

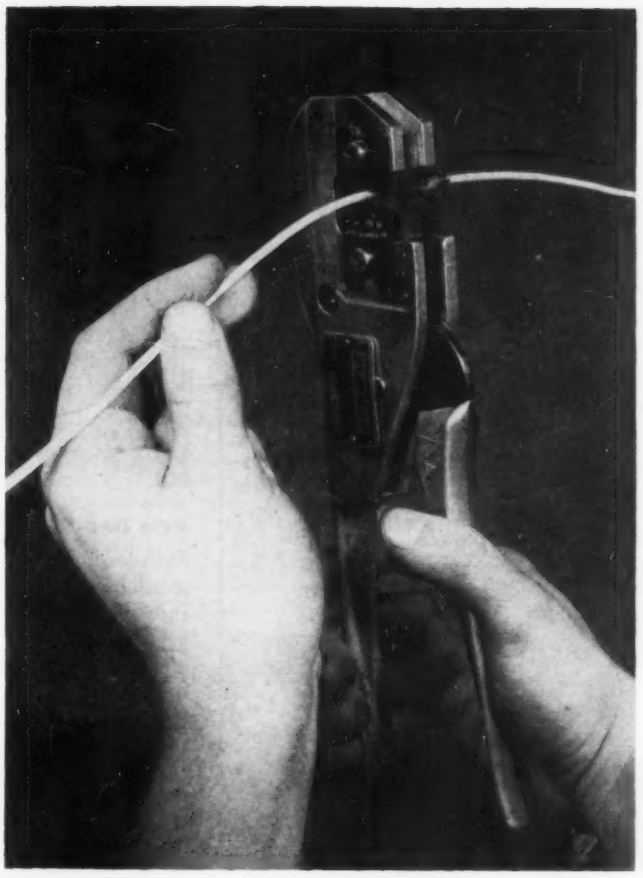
There is no theoretical limit to this ratio since an increase in the conductive area of the splice—provided a good connection is made between the cable and the splice—increases the ratios proportionately. For this reason design is normally guided by practical considerations. A ratio of less than unity should not be tolerated since it results in a higher resistance over the splice length than the resistance of the cable over an equivalent length. A ratio of 1.00 is adequate.

$$\text{Dielectric Ratio} = \frac{\text{insulating value of splice dielectric}}{\text{insulating value of cable dielectric}} \quad (E)$$

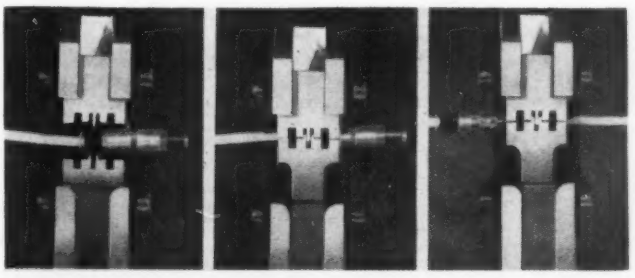
For the same reasons given in the conductivity ratio, a dielectric ratio of 1.00 is adequate. Any requirement in excess of unity is not realistic—although it can readily be achieved. Acceptance of less than 1.00 detracts from the value of an "insulated splice".

The purpose of any splice is to restore the original integrity of a cable. In designing the Sealink family of insulated splices, Burndy engineers considered environmental insulation a major design factor. For this reason they isolated the copper conducting link from the environment by means of a "gasketing" principle, thus restoring the full character of the cable to the splice. Burndy engineers feel they have come up with a radical improvement in the technique of splicing for application engineers because their tool-installed Sealink splice isolates moisture from the connection without the need of tape. Performance characteristics based on the above quantitative analysis are given in the table for four types of splices designed to cover the indicated ranges of copper aircraft cable sizes. Similar information should be readily obtainable from other cable splice manufacturers for comparative analysis purposes.

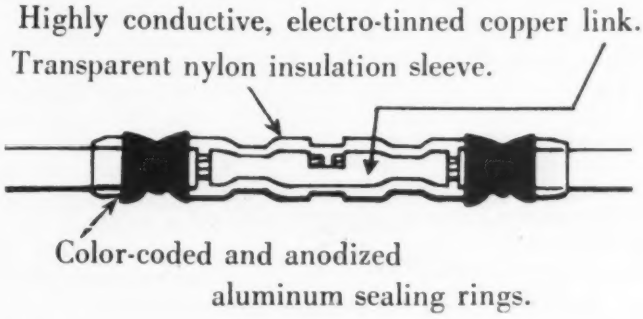
**For more information and literature on insulated splices circle number 127 on the Reader-Inquiry Card.**



**Installing the Sealink is a rapid, uniformly controlled, simple operation. Hand operated Hytools have ratchet action controlling depth of indent and insuring completed crimps. The installation is completed without reversing the tool—a crimp on each end of the splice connects and seals. The connector is always correctly crimped as the Sealink is designed with a center locating groove. The reduced thickness of the nylon at the center of the connection makes inspection easy.**



***Left.* With Sealink firmly positioned in the sliding stop-plate of the tool, the inserted wire butts against the splice's built-in internal stop. *Center.* One crimping operation seals and crimps one end of the splice. *Right.* The second end is positioned and crimped in the same manner.**

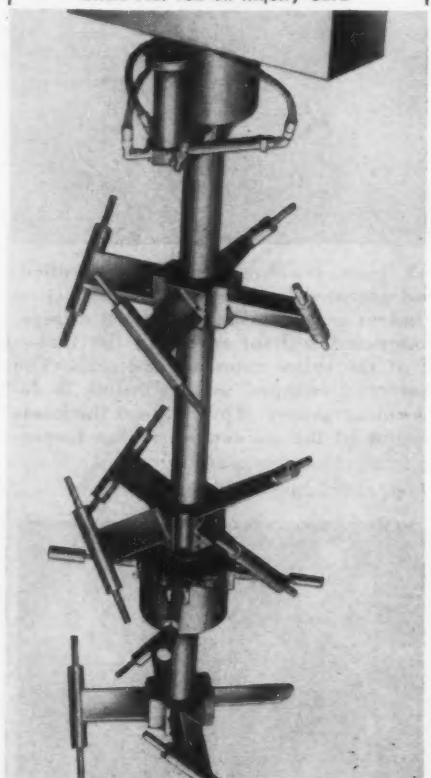


**COMPONENTS**

### Drone Command Antenna

Ruggedized version of a UHF, 3 bay, circularly polarized, omnidirectional antenna has been designed for unusual environmental conditions and is suitable for ship board applications. The all aluminum AT-781/U, has a vertically stacked array of four quadrature unipoles between the 2nd and 3rd bays to improve overhead coverage, and is pressurized to increase power handling capabilities and prevent breathing. Gabriel Electronics Division, Needham Heights, Mass.

Circle No. 152 on Inquiry Card



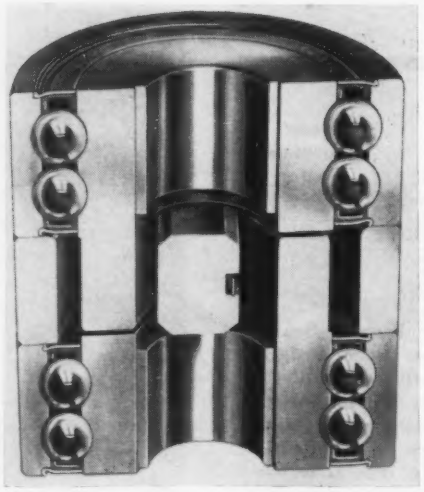
WORTH FILING

### Ultrasonic Cleaning

24-page booklet explains basic principles of modern ultrasonic cleaning methods and discusses application areas, equipment design considerations, batch immersion, conveyor and multistage systems. Information on solutions and chemicals for ultrasonic cleaning and a number of methods of evaluating performance are given.

Source: Branson Ultrasonic Corp.
Stamford, Conn.

For your copy: Circle No. 149 on Inquiry Card



### New One-Way Torque Bearings

Standard bearing assemblies are now available which prevent independent movement of a driven shaft except when rotation is produced by a drive shaft. Both shafts insert in the bearing assembly. Two conventional double row ball bearings, with extended inner rings, are used on either end. Between the two is a lock ring containing a spring-loaded lock bar. As shown, drive shaft rotation compresses the spring and releases the lock bar. This permits rotation to be transmitted to the driven shaft. However, any independent driven shaft movement will cause the lock bar to wedge tight against the fixed outer lock ring. Driven member lash is less than two degrees; drive shaft lash is less than 4.5 degrees. Applications include steering mechanisms, aircraft controls, hoists, derricks, punch presses and ordnance turrets. Standard torque ratings range from 50 pound-inches to 2600 pound-inches. Bearings are machined to ABEC-1 specifications, or to customer specifications. Ann Arbor Bearing & Manufacturing Co., Ann Arbor, Mich.

Circle No. 178 on Inquiry Card

### Physical and Thermodynamic Properties of Helium

Jesse P. Simmons
William R. Whittacker Company,
915 N. Citrus Avenue,
Los Angeles 38, California, $10.00

If you are using pressurized helium to control the flow of liquid fuel in missiles, you need precise data on the physical and thermodynamic properties of this gas. Here's a report that summarizes currently available information on the physical and thermodynamic properties of gaseous helium. Design equations and data are presented in both tabular and diagrammatic form to facilitate its use and application both in design and test situations. For your copy write directly to the company.

### Tachometer

Combining a standard BuORD size 11 motor with an integral high performance 400 cycle (125°C ambient operating temperature) damping tachometer in a casing 2-19/32" long, provides a compact and versatile means of systems stabilization with low inertia, low power consumption, damping applications and high temperature reliability. Complete technical data available on request. Mechatrol, Westbury, L. I., N. Y.

Circle No. 90 on Inquiry Card

### Proximity Transducer Systems

A variety of manufacturing operations is automated through use of proximity transducer systems that are engineered for high speed control operation, difficult environmental conditions, and relatively long range sensing—up to six inches and more.

The basic system consists of a pick-up mounted at the point of work a shielded connecting cable and a control unit. The presence of metallic workpieces near the pickup causes the connected control unit to provide an electrical pulse that governs associated mechanical or electronic production operations.

The system is suitable for a variety of industrial automation control applications, for example: two transducers systems are used to control a tube cutting and deburring process; an automotive manufacturer is using a system to sense gears on a conveyor which then energizes a motor that causes the gears to be moved onto a spindle for a subsequent operation; and an electronics manufacturer uses a hollow proximity pickup coil to count mounting studs. Electro Products Laboratories.

Circle No. 159 on Inquiry Card

## ADVERTISERS' INDEX

| ADVERTISERS | Page Number | Inquiry Number |
|---|---|---|
| **A** | | |
| Ace Electronics Associates Inc. | 23 | 11 |
| **B** | | |
| H. O. Boehme, Inc. | 22 | 10 |
| **C** | | |
| Clifton Precision Products Co. Inc. | Cover 4 | 29 |
| Consolidated Electrodynamics Corp. | Cover 2 | 1 |
| Consolidated Electrodynamics Corp. | 27 | 12 |
| Continental Wire Corp. | 13 | 6 |
| **D** | | |
| The Daven Company | Cover 3 | 28 |
| Diamond Antenna & Microwave Corp. | 34 | 21 |
| **F** | | |
| Fitzpatrick Electric Supply Co. | 32 | 18 |
| **G** | | |
| G-V Controls | 11 | 4 |
| **K** | | |
| Kinney Mfg. Div., *The New York Air Brake Company* | 39 | 23 |
| **L** | | |
| LaPointe Industries Inc. | 43 | 25 |
| **M** | | |
| Marion Electrical Instrument Co. | 11 | 5 |
| Peter Mehlich Organization | 40 | 24 |
| **N** | | |
| The New York Air Brake Company | 39 | 23 |
| **P** | | |
| George A. Philbrick Researches Inc. | 28 | 13 |
| Post Machinery Co., *Electronics Div.* | 18 | 7 |
| **S** | | |
| Saginaw Bearing Company | 18 | 8 |
| Southwest Products Co. | 31 | 16 |
| Southwest Products Co. | 34 | 20 |
| Split Ballbearing, *Div. of MPB, Inc.* | 32 | 17 |
| Split Ballbearing, *Div. of MPB, Inc.* | 47 | 27 |
| Standard Plastics Co. Inc. | 29 | 14 |
| **U** | | |
| United Electric Controls | 35 | 22 |
| United Electric Controls | 33 | 19 |
| Unitek Corp., *Weldmatic Div.* | 29 | 15 |
| **V** | | |
| Valcor Engineering Corp. | 7 | 3 |
| Victoreen Instrument Co. | 19 | 9 |
| **W** | | |
| Edwin L. Wiegand Co. | 47 | 26 |
| **Y** | | |
| Yardney Electric Corp. | 2 | 2 |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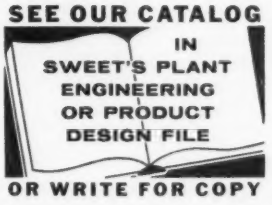


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STAFF COLUMNIST

**David Bandel**
*Associate Technical Director,*
TRACERLAB, INC.

# ALPHAS & BETAS OF IONIZATION

Present day instruments for measuring radioactivity depend to a large extent upon the ionizing potential of the radiation. Refinements in the art of measuring very small electrical currents and potentials have served mainly to push the limits of detection and measurement of radioactivity to the point where the statistical nature of the nuclear disintegration process has become the ultimate barrier to increased accuracy of measurement.

Ions are produced by radioactive materials either as primary products of nuclear disintegration or as secondary products of the interaction between gamma photons and matter. Primary ions are alpha and beta particles. Alpha particles are doubly charged positive helium nuclei; beta particles are electrons and carry a negative charge. Characteristics of these particles differ markedly. Alpha particles have short range and poor penetrating power so they produce their effects within a relatively small volume. Also, they are monoergic, they have a narrow energy distribution. Beta particles have a much longer range and can penetrate metal foils and low density materials. Because of the longer range they can produce effects at some distance frrom their source. Energy distribution of beta particles is very broad and they are usually listed according to the maximum energy of the particles; average energy is approximately 1/3 of the maximum.

## STATIC ELIMINATION

Practical applications of ionizing properties of radioactive materials have been few. One of the first applications has been dissipation of electrostatic charges. Materials of moderate to high electrical resistivity pick up charges during processing. Friction is not necessary for charge build-up; dissimilar surfaces brought into contact and separated can acquire electrostatic charges. On textile materials charges in the range of 1-10 ESU/cm$^2$ are common during weaving. Discharge is accomplished by the use of ionizing radiation to supply ions to the surrounding atmosphere and neutralize or bleed off the charge on the material. Silent electrical discharges can also be used to ionize the air but is rarely used.

Radium and its decay products, such as polonium 210, in the form of thin foils function as static eliminators. These radioisotopes are primarily alpha emitters and produce high local concentration of ions in the surrounding atmosphere. Optimum distance in air is about 7 cm for radium alpha particles. Chief disadvantages of radium are its relatively high cost and that it emits gamma radiation, introducing a radiation hazard problem. Polonium is better in this respect but is expensive and has a short half-life.

More consideration has been given lately to the use of beta emitters as static eliminators. Pure beta emitters, with no gamma components, are available at low cost. Among the more promising are strontium 90, thallium 204 and krypton 85. Where a slow rate of discharge is sufficient, beta sources are practical; paper tapes for teletype and recording charts are illustrations. Solid radioactive sources represent a potential hazard, although past experience has shown this hazard to be minor with proper fabrication techniques for the capsules. One face of the capsule, the window, is a thin stainless steel sheet which permits beta particles to pass into the atmosphere without excessive losses by absorption. There is the possibility the capsule might develop a leak if handled carelessly. Krypton 85, however, is a gas and rupture of a capsule results in rapid dissipation of radioactivity into the atmosphere. Krypton 85 also permits more geometric freedom in designing beta sources. Constant flux can be maintained with a gaseous source that would be difficult to attain with solid sources.

## GAS DISCHARGE TUBES

Radioactive isotopes in gas discharge tubes stabilize the breakdown voltage by reducing the statistical time lag to virtually zero. Under normal operating conditions discharge will not occur until a sufficient number of free electrons or ions appear in the gaseous space between the electrodes. This requires time, even when the applied voltage exceeds the discharge voltage of the tube by a considerable amount. It is standard practice to introduce a small quantity of radioactive isotope into the tube envelope to maintain an atmosphere of free electrons or ions to initiate instant firing of the gas as soon as the breakdown voltage is attained. Very small quantities of cobalt 60 salts are applied to the tube envelope and deposited by evaporation of the solvent. Krypton 85 is an ideal source of ions for gas fills at atmospheric or near atmospheric pressure. Tests have been run with an argon fill containing 100 microcuries of krypton 85 in 15 ml of argon at atmospheric pressure. Successive discharges in a closed spark gap occurred at voltages reproducible to about $\pm 0.5\%$. In the case of cold cathode tubes, where low pressure gas fills are common, the softer beta radiation from tritium is more efficient. Tritium is readily adsorbed by glass under silent electric discharge conditions. Tritium is also strongly adsorbed and held in films of zirconium and titanium. A small quantity of ionizing radiation reduces the starting time and voltage of fluorescent lamps.

## OTHER POSSIBLE USES OF RADIATION IONIZATION

Some suggestions have been made for other applications of the ionizing abilities of radioisotopes. In industrial fine grinding operations there is a tendency for some materials to agglomerate when particles reach a critical size. This effect is probably due to the build-up of static charges on the particles, impairing grinding efficiency. Frequently, dispersing agents must be added to prevent agglomeration. It might be possible to ionize the air in the grinding mill by a suitable radioactive source and continuously bleed off any static charges that accumulate on the particles. This would be of considerable importance in the cement industry, where fine-grinding is a large scale operation.

One interesting possible application of ionizing sources that was suggested several years ago is the control of combustion. According to some theories of flame propagation, "useful" flames are propagated by ionic mechanisms; detonation is caused by free radical flame propagation. Lead tetraethyl, which has a long and hairy history as an effective anti-knock additive, is capable of producing free radicals at elevated temperatures. The mechanism of its anti-knock action is thought to be termination of the free radical propagated flame in the combustion space by the radicals derived from the lead tetraethyl. Pre-ionization of the fuel-air mixture might enhance the ionic, or "useful" flame propagation rate by increasing the number of initiating centers. This would effectively reduce knocking and permit the use of lower octane fuels. Faster flame propagation might also be useful in jet engines.

CIRCLE 28 ON INQUIRY CARD→

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This unit is available as a single pole, 10 position switch and can be obtained with up to four poles on a single deck.

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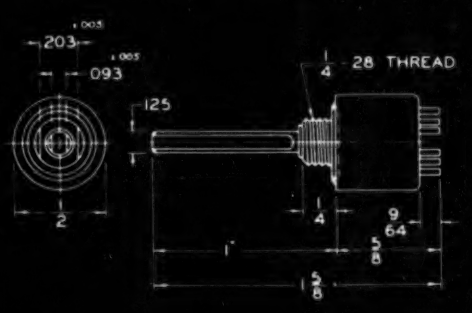
**Insulation Resistance:** 200,000 megohms between any two terminals or between any terminal and shell. Measured at 25° C., 50% RH, at sea level.

**Life Expectancy:** 50,000 cycles minimum

Shaft and case: Stainless steel
Panel and hub: Glass filled epoxy
Contacts and terminals: Silver alloy
Rotors: Rhodium plated beryllium copper



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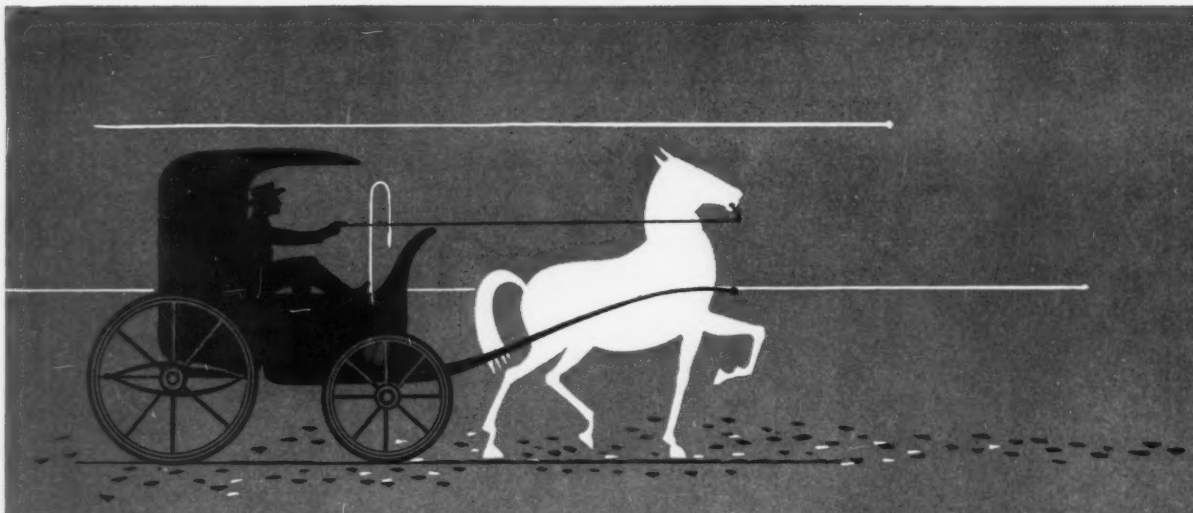

# RELIABILITY or

## The Wonderful One-Hoss Shay

### *A Logical Story*

Have you heard of the wonderful one-hoss shay,
That was built in such a logical way
It ran a hundred years to a day?

"For," said the Deacon, "It's mighty plain
That the weakest place must stand the strain;
And the way to build it is only jest
To make that place as strong as the rest."

The Deacon followed the two cardinal principles for reliability.

1. Know the stresses your component will be subject to (in other words know the environment).

2. Build faithfully to the specifications that *cope* with this environment.

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